LATERAL BIASES IN SHAPE FROM SHADING: THE ROLE OF NATIVE READING DIRECTION

A Thesis Submitted to the College of Graduate Studies and Research

In Partial Fulfillment of the Requirements

For the Degree of Master of Arts

In the Department of Psychology

University of Saskatchewan

Saskatoon

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ABSTRACT

The human visual system has learned to assume that light originates from above, most likely because of the persistent natural overhead light source – the sun (Ramachandran, 1988). Asymmetries of perception in neurologically normal individuals, like assuming light is coming from above, in part result from efficiency measures of the visual system. Not only is light assumed to come from above, but light from above and to the left has been found to decrease reaction times in target finding as well as increase aesthetic preference (Sun & Perona, 1998; Smith & Elias, 2013). The underlying cause of the bias towards upper-left lighting is debated, and may have a relationship with another peculiar phenomenon in neurologically normal individuals where greater attention is paid to leftward space, called pseudoneglect (Bowers & Heilman, 1980). Alternatively, an explanation suggesting that directional reading influences lighting preferences has been proposed, as Smith and Elias (2013) found native right-to-left readers to be significantly different from leftward biased left-to-right readers. The current set of experiments used eye-tracking and a target finding paradigm to assess differences between left-to-right and right-to-left readers. Manipulating the position of the light illuminating a field of spheres generated targets, creating either 1 convex bubble among 15 concave depressions, or vice-versa. Results from these studies are mixed, and highlight differences between both upper and lower and lateral visual space. Light originating from above facilitated shorter average duration times for both groups, whereas left-to-right readers tended to prefer light from the upper-left, while right-to-left readers preferred light from the upper-right. No one target location in the array facilitated shorter average duration times for right-to-left readers, although left-to-right readers tended to exhibit shorter durations when identifying targets in the upper-left quadrant. Participants spent the greatest amount of time examining the upper quadrants of the array, tending to focus more on the side of the image that their native reading direction begins on. The influence of directional reading on light source perception, and the potential problems of using exclusively Western participant samples are discussed.

ACKNOWLEDGMENTS

This thesis work was only possible because of the support from many people. My greatest thanks go to my family and friends who have graciously endured countless thesis conversations and understood when I have prioritized thesis work over them. Most importantly I am thankful to my parents, Karen & Knute, my Aunt Noella, and my sisters, Anna & Siri, for nurturing my desire to continue learning. I am exceptionally thankful for the encouragement and patience of my wife, Nicole – I would certainly not be where I am without her.

Many thanks to my fellow graduate students and department faculty members for the meaningful conversations, encouragement, and valuable feedback on my research. I would like to especially thank other members of the Elias lab for all their help, both formal and informal. Additionally, I would like to thank my advisory committee, Dr. Ron Borowsky, Dr. Janeen Loehr, and my external examiner Dr. Carl Gutwin, for the time they have dedicated to reading and providing feedback on this thesis. I am particularly thankful to Dr. Ron Borowsky for statistics help and Dr. Janeen Loehr for writing help.

Lastly, innumerable thanks are due to my graduate studies supervisor, Dr. Lorin Elias. Working together and learning from him has been invaluable. I cannot imagine a finer collaborator.

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CHAPTER 1

INTRODUCTION

Asymmetries of perception in neurologically normal individuals occur in line bisection (McCourt, 2001), image comparisons (Nicholls, Bradshaw, & Mattingley, 1999), aesthetics (Chokron & De Agostini, 2000), and shape from shading (Sun & Perona, 1998). The underlying cause of these biases, as well as *if* indeed there is a shared underlying mechanism, is debated. Asymmetries of perception and attention are often biased towards the left, documented extensively in literature exploring this phenomenon, known as pseudoneglect (Bowers & Heilman, 1980). Established methods for evaluating pseudoneglect have elicited mixed results when applied to populations with native languages that read and write in directions other than left-to-right (Chokron & Imbert, 1993; Fagard & Dahmen, 2003). A recent study by Smith and Elias (2013) supports the premise that native reading direction is important in modulating leftward lighting biases and aesthetic preference. Our existence on a planet with a single overhead light source, the sun, has optimized the human visual system for perceiving light from above (Ramachandran, 1988). That light is preferred to originate from above and to the left is not as easily explained. By accounting for participants' cultural differences, in particular for their native reading direction, leftward biases of perception, attention, and aesthetics have been more clearly understood (Chokron & Imbert, 1993; Chokron & De Agostini, 2000; Fagard & Dahmen, 2003). To assess the potential influence of native reading direction on light source perception and target identification we monitored the eye movements of two groups of participants with native languages that read and write in opposite directions while they observed simple shaded stimuli in a target finding array. Findings from these studies suggest that learning a language that reads and writes right-to-left, rather than left-to-right, alters performance on a shape from shading target-finding task.

Visual system assumptions

The human visual system learns how features like light and dark, motion, and colours, fit together to produce seemingly simple images. A unified picture of the external world is constructed through information from saccadic, choppy, eye movements. Because of the large amount of information that constantly enters the visual system, it selectively attends to certain elements, and learns when short cuts and assumptions can be made to increase efficiency and save time. Examples of these assumptions are found in colour vision, the blind spot, and shading two-dimensional (2D) images to appear three-dimensional (3D). Photoreceptors do not receive colour information across the entire visual field, yet the areas perceived by the black and white photoreceptors appear colourful, because the brain extrapolates based on concurrent visual information from closely surrounding areas. When the dot disappears in the blind spot test, it enters the area of the visual field that projects to the optic disc, where there are no sensory photoreceptors. The dot does not disappear behind a dark or blank spot, rather existing visual information *covers* the blind spot and the visual field appears seamless. Perceiving a 2D image as 3D is achieved by using shading cues, more commonly referred to as perceiving shape from shading. Artists increase realism to paintings by adding shading to a scene that is consistent with the other surrounding elements, and also with how the observer would expect to experience it in real life.

When perceiving shape from shading, circles shaded vertically, that is, shaded darker at the top than the bottom (or vice-versa), appear to be three-dimensional spheres, but when shaded from horizontal angles approaching 90 degrees, this illusion disappears (Kleffner &

Ramachandran, 1992). Ambiguously lit stimuli are processed by the human visual system using prior assumptions about the location of the light source as well as about the shape and form of the object – and what the end result of these two factors interacting should be (Langer & Bulthoff, 2001; Mamassian & Goutcher, 2001; McManus, Buckman, & Woolley, 2004; Ramachandran, 1988).

Searching for a unique target among distractors, opposed to a target that is in some way defined by a conjunction of features of the distractors, leads to quicker target identification times (Treisman, 1986). These different situations highlight 2 methods used in visual search, serial and parallel search. Stimuli in the studies presented here represent unique stimuli among distractors, and thus a parallel search strategy, as shape from shading creates the illusion of one target popping out (or sinking in) from the distractors. Additionally, it follows that the number of the distractors does not impact the amount of time taken to identify the target, as the individual is not required to focus attention on each item in turn (Treisman, 1986).

As light from above creates a convex image (Ramachandran, 1988) convexity is assumed rather than concavity when perceiving shape from shading (Langer & Bulthoff, 2001). The effects of lighting differences in 3D perception have been examined in experiments using egg and dimple stimuli (Kleffner & Ramachandran, 1992), raised and depressed undulating lines stimuli (Mamassian & Goutcher, 2001), the Polo Mint stimulus (Gerardin, de Montalembert, & Mamassian, 2007) and textured cylinder stimuli (Langer & Bulthoff, 2001). However, prior assumptions made by the visual system can change, as Adams, Graf, and Ernst (2004) and Champion and Adams (2007) have shown the light from above and convexity priors to change through haptic training.

Investigating perceptual biases in light source perception is certainly not a recent endeavour. Observations by Rittenhouse (1786) about the apparent reversal of valleys and ridges on the moon's surface, when the light changed, are some of the earliest about lighting and shading. Consideration of this phenomena led Rittenhouse to carry out simple experiments wherein light was manipulated as it illuminated the bricks on his hearth. He found that inverting the light caused the ridges of the bricks to appear as depressions, and the depressions between the bricks to appear as ridges.

Leftward lighting bias & cultural Influences

It is not entirely clear why, but we assume light to be not only from above, but also from above-left. The leftward lighting bias seems to have no intuitive explanation, unlike light from above being preferred. In fact, how and why the visual system developed a bias for light from any direction are perplexing questions. One is hard pressed to think of any group of people across time that may have been in a situation where light originated from one direction more than any other. Studies examining a leftward bias for lighting have not found one optimal light source position for the human visual system, but evidence suggests above-left lighting facilitates faster target finding performance and a more stable 3D percept (McManus et al., 2004; Sun & Perona, 1998; Mamassian & Goutcher, 2001). Curiosity and scientific exploration into lighting asymmetries have been fuelled by German Gestalt psychologist Wolfgang Metzger's early observation of left light and right light not being perceptually equivalent (as in Sun & Perona, 1998), as well as by phenomena like leftward line bisections in neurologically normal individuals (Bowers & Heilman, 1980).

A meta-analysis of line bisection tasks (Jewell & McCourt, 2000) concluded that directional scanning of a stimulus is one factor that regulates lateral biases. Jewell and McCourt suggest that line bisection tasks not controlling for scanning direction are open to confounds.

Abed (1991) found that when examining stimuli, individuals who read and write English make more left-to-right eye movements, and oppositely, to a lesser degree, right-to-left reading individuals make more right-to-left eye movements. As many previous studies have used English participants from Western institutions, the leftward-lighting bias could therefore, in part, be a result of a sample of individuals who spend more time examining the area where their scans start – the left.

Manipulation of the shading of 2D circles to mimic a moving light source has proven to be an effective method in determining assumptions that the human visual system makes about light sources (Elias & Robinson, 2005; Ramachandran, 1988; Sun & Perona, 1998). In Pasadena, California, Sun and Perona (1998) constructed a target finding paradigm using 24 shaded circles in an array as stimuli. The shading gradient of the array was consistent within the distractors and the target was always oppositely (180 degrees) shaded. Lighting varied with each trial, with only half of the trials containing a target. Quicker reaction times for target identification were observed when the field appeared to be left-lit.

At the University College London, McManus et al. (2004) presented shaded circles as stimuli one at a time as well as in groups of 16 to examine the leftward lighting bias in diverse scenes. When stimuli were presented in a group the preferred lighting angle was leftward. When a single circle was presented, however, no bias towards left lighting was observed, with the preferred lighting angle being 0.5 degrees right of centre. Elias and Robinson (2005) at the University of Saskatchewan also investigated light source assumptions using shaded circles as stimuli, although stimuli were presented either one at a time or in mirror reversed pairs, one on top of the other. The leftward lighting bias was observed both when a single stimulus was presented and when two stimuli were simultaneously presented.

The leftward lighting bias has been replicated using stimuli other than shaded circles, as well. In Glasgow, Scotland, Mamassian and Goutcher's (2001) stimuli were images with wavy horizontal lines of varying widths and shading. Mamassian and Goutcher found individuals to perceive ambiguously shaded images as three-dimensional most strongly when appearing to be lit from above-left. Mamassian et al. (2003) suggest that brain activity mirrors these behavioural biases. Using the same stimuli, Mamassian et al. report that the N2 component of event-related potentials in the occipital, temporal, and parietal regions was modulated by stimulus orientation, or apparent lighting direction.

The influence of native reading direction

Throughout the behavioural sciences a common trend is to collect data from undergraduate students at Western universities (Henrich, Heine, & Norenzayan, 2010), with few researchers accounting for the differences that may exist between groups with opposite directions of reading, or other cultural factors. Until a recent study by Smith and Elias (2013), there had been no interest in examining the potential influence of reading direction on light source perception. Past research examining lateral biases, while considering native reading direction has yielded compelling interactions, justifying our further exploration into lighting biases and native reading direction.

Abed (1991) found non-directional scenes to be explored in a similar fashion to directional ones, like text. Maass, Suitner, Favaretto, and Cignacchi (2009) compared left-to-right Italian and right-to-left Arabic readers' performance on a task examining spatial biases and the agency of different groups. Maass et al. found Italians to place the more agentic group to the left, and Arabic individuals to display the opposite trend by placing the more agentic group to the right. Morikawa and McBeath (1992) used still images of rows of diamonds and replaced them with either another row of diamonds that was shifted left or right, creating an illusion of motion, or with a row in the same position as the original. Participants indicated in which direction the row appeared to be moving. Left-to-right readers displayed a significant leftward motion bias, while right-to-left readers displayed no bias. Morikawa and McBeath suggest that the difference arises because of the eye movements associated with learning to read a certain language.

By comparing children before and after learning to read and write Fagard and Dahmen (2003) provide convincing evidence for the influence that language has on spatial biases. Fagard and Dahmen compared French (left-to-right reading) and Tunisian (right-to-left reading) children aged 5, 7, and 9 across three measures: line bisection, circle drawing, and dot filling. French children made greater leftward line bisections than Tunisian children with differences becoming significant, with both the left and right hand, by age nine. From age 7 and on, Tunisian children followed a pattern of clockwise drawing while counter clockwise movements were found in French children. Again at age 7, significant differences arose between the two groups on the dot-filling task as French children were able to fill in more dots moving left to right, and Tunisian children filled more dots in moving right to left (Fagard & Dahmen, 2003).

In reading tasks, Nazir, Ben-Boutayab, Decoppet, Deutsch, and Frost (2004) reported higher accuracy in identifying a target letter among a string of letters in the right visual field for native right-to-left reading Hebrew participants and the left visual field for native English readers. Additionally, saccades were found to be overall rightward for Hebrew readers and leftward for English readers. Pollatsek, Bolozky, Well, & Rayner (1981) also used a reading task with Israeli participants who read both Hebrew and English. Conditions for how much text was visible to the left and right varied, and it was found that performance was superior for reading Hebrew when more leftward text was revealed, as opposed to better performance when more rightward text was visible for English reading. Spalek and Hammad (2005) found differences between Canadian and Egyptian students on the inhibition of return (IOR) measure of attention. Inhibition of return suggests that when searching for a target, an attentional mechanism biased to novel locations causes slower (inhibited) visual searches to locations that have already been examined. Left-to-right reading Canadians had a larger left-to-right inhibition of return effect, while a larger inhibition of return effect for right to left movement was observed among the Egyptian group.

Native reading direction has also been found to reverse biases in aesthetics. González (2012) compared the composition of left-to-right reading Spanish and right-to-left reading Iranian portrait photographs. González examined a representative sample of 19th century photography books, taking note of 5 compositional elements: linear order; couples; chairs; tables; and portraits. Inspecting portraits for linear order, where groups were arranged by height, couples, where one person is sitting and one is standing, and chairs, where the subject stands and rests on the chair, Spanish photos showed a left-to-right directionality while Iranian photos displayed an opposite right-to-left directionality. Table portraits, where the subject sits and rests on the table also revealed opposite results in Spanish and Iranian photos, but reversed, as the subject was placed to the right of the table significantly more in Iranian photos and to the left significantly more in Spanish photos. In portraits, which are a single person with no props, Spanish photographs show the sitter's left cheek significantly more than in Iranian photos.

Chokron and De Agostini (2000) assessed aesthetic preference of adult and children native left-to-right (French) and native right-to-left (Israeli) readers. Participants compared 30 mirror pairs of images, 10 conveying motion, 10 static objects, and 10 landscapes; half of the images displayed left-to-right directionality, and half with opposite right-to-left directionality.

Chokron and De Agostini found participants' picture preferences to match the directionality of their reading habits. Left-to-right readers (both adults and children) preferred left-to-right directionality significantly more in static and motion images, and non-significantly (but in the left-to-right direction) for landscapes. Right-to-left reading adults displayed right-to-left directionality biases for static and motion images, while children displayed no bias. Like French adults Israeli adults preferred landscapes with pictures located in the right half of the page. Israeli children also displayed this bias, but not significantly so.

Similar to González (2012), Thomas, Burkitt, Patrick, and Elias (2008) examined posing biases of participants but in full-page English language magazine advertisements. Differences were found based on the sex of the subject, as well as the amount of body visible (head only, head and shoulders, head to waist, and entire body). Males tended to show a rightward posing bias for head only, head to waist, and entire body images. Females displayed an opposite overall trend of a leftward bias in head to waist advertisements and non-significantly, but in a leftward direction, for head only and entire body advertisements. Thomas et al. also examined the lighting of magazine advertisements, exploring the possibility of a real-world lighting bias. Of their sample, more left-lit advertisements were identified than centrally or right-lit.

Hutchison, Thomas, and Elias (2011) also report an aesthetic preference for leftward lighting using left and right-lit advertisement-style images. Using only English participants, images were given a rating when presented independently, and one image was chosen as preferred when presented in a group. Group presentations included a single image in both the right-lit and left-lit conditions (mirrored) and viewed one on top of the other. Participants rated left-lit images higher in feeling toward brand name, and feeling toward advertisement, while purchase intention was rated higher under left lighting and approached significance. Overall ratings for left-lit images were more positive than for right-lit images, although no significant preference was reported for group presentations.

Sun and Perona (1998) suggest that top left lighting may have higher perceptual value, as the light source in 225 master paintings, across varied schools and periods, was predominately upper-left. McDine, Livingston, Thomas, and Elias (2011) flipped the artistic paradigm by giving control of the light source to individuals. When examining abstract artwork, individuals were asked to illuminate abstract artwork in the most aesthetically pleasing manner. The leftward lighting bias was again observed, as individuals consistently placed the light source in the top left.

A solution that explains differences between groups with opposite reading directions has yet to emerge. In part, there are no definite explanations because of the variability between studies, and between tasks within a single study, comparing opposite reading direction groups (Barrett, Kim, Crucian, & Heilman, 2002; Chokron & De Agostini, 2000; Nicholls & Roberts, 2002; Ishii, Okubo, Nicholls, and Imai, 2010). Like Chokron and De Agostini, Ishii et al. compared Japanese and English readers using mobile, static, and landscape stimuli preference judgments (Japanese read right-to-left at the at the line level and top-to-bottom at the word level). Additionally, participants completed 15 line bisections. Results for motion and static images are consistent with Chokron and De Agostini, with leftward directionality observed among left-to-right readers and an opposite rightward directionality for Japanese individuals. On the landscape task Ishii et al. report a rightward preference for right-to-left readers, similar to Chokron and De Agostini, but no bias for left-to-right readers. In line bisection, leftward bisections were observed in both groups, with Japanese readers making greater leftward deviations. Mixed directionality of lines and words in Asian languages, as in Barrett et al. & Ishii et al., may contribute to the variability observed in studies with mixed results.

A relationship with pseudoneglect

It is not known if the leftward lighting bias is in any way related to pseudoneglect, the leftward attentional bias found in neurologically normal individuals. Pseudoneglect occurs in neurologically normal individuals when they misperceive objects in the left hemifield as brighter, more numerous, and larger than those in the right hemifield, even if there is no difference in brightness, numerosity, or size (Nicholls et al., 1999). The right hemisphere's superior processing of spatial information has been proposed as partially responsible for leftward biases (Davidoff, 1975; Levy, 1976; Chokron & Imbert, 2003). It is believed that this right parietal activation is tied to the preference, or overestimation of leftward space observed in pseudoneglect. Nicholls and Roberts (2002) have suggested asymmetries in the neural mechanisms that control attention as a complementary, or alternative, explanation. The hand used to perform a task, handedness, age, sex, and reading direction, have been identified as factors affecting the severity and even direction of leftward biases (Jewell & McCourt, 2000). Pseudoneglect mirrors (and gets its name from) neglect (also known as hemi-spatial neglect or clinical neglect), as neurologically damaged patients – often due to a right parietal cortex infarct – tend to neglect the left side of space (Bowers & Heilman, 1980; Bradshaw, Nettleton, Nathan, &Wilson, 1985). The nature of a relationship, if any, between the neural mechanisms involved in the leftward lighting bias and other lateral asymmetries, including pseudoneglect, is not known.

When asked to place a marker at the middle of a line in a line bisection task, neurologically normal individuals will consistently bisect the line to the left of centre (Bowers & Heilman, 1980; Jewell & McCourt, 2000). Some have failed to reproduce a bias in leftward bisections (Manning, Halligan, & Marshall, 1990) while others have found the leftward bias to occur robustly across variations of classical line bisection.

In a forced choice tachistoscopic line bisection, where participants must decide if a pre-bisected line has a leftward or rightward bisection, McCourt (2001) found leftward errors in 91% of cases. Using horizontal, vertical, and radial haptic line bisection Cattaneo, Fantino, Tinti, Pascual-Leone, Silvanto, and Vecchi (2011) found neurologically normal blind folded sighted and blind participants to have a leftward bias in the horizontal condition. Additionally, sighted individuals were found to have downward and proximal biases of the vertical and radial conditions. Using an adapted line bisection task, Regolin (2006) demonstrated pseudoneglect effects with 9-day-old chicks. Birds were trained to peck at the centre bead. Side pecks were fewer than central pecks, but mistakes that were made were significantly leftward. Turning to the animal model can be useful in studying asymmetric perception, as the avian visual system is lateralized both anatomically and functionally.

Mattingley, Bradshaw, Nettleton, and Bradshaw (1994) report similar spatial biases in neglect patients and controls in the greyscales task and when examining chimeric faces. The greyscales task is a forced choice discrimination task between two bars that incrementally change from white on one side to black on the other (Mattingley et al., 1994), while the chimeric faces task fuses two faces, of different emotions, together (Levy, Heller, Banich, & Burton, 1983). When asked to determine the darker rectangle and the happier face, neglect patients showed a rightward bias and the control group demonstrated an opposite leftward bias. In neurologically normal individuals it appears that this leftward attentional bias does not depend on any specific feature as Nicholls et al. (1999) demonstrated the leftward attentional bias irrespective of target (lighter/darker, more/less numerous, or bigger/smaller) in the greyscales, star, and shape tasks.

Nicholls, Loftus, Orr, and Barre (2008) as well as Thomas, Stuckel, Gutwin, and Elias (2009) found a similar overestimation of leftward space during collision tasks. Nicholls et al. reported more collisions on the right than the left when passing through a doorway while dialing a phone with the either the left, right, or both hands. Using a virtual environment Thomas et al. found more rightward collisions only when routes were followed in the upper visual field, or in the central condition by left handed individuals.

In addition to lateral differences, attentional inequalities between upper and lower visual fields have been identified (Christman & Niebauer, 1997). As with lateral biases, explanations for upper and lower visual field advantages are heterogeneous and often contradictory of one another. Typically, advantages in the lower visual field include performance on contrast sensitivity, motion, and visual acuity; while local processing, categorical judgments, and visual search are superiorly processed in the upper visual field (Karim & Kojima, 2010; Thomas & Elias, 2011). Previc (1990; Previc & Blume, 1993) suggests a model in which visual field advantages rely on where in space, extrapersonal or peripersonal, a task is carried out. Accordingly, a target finding task occurs in focal extrapersonal space (FcE) and yields upper visual field advantages first, and right visual field advantages second (Previc & Blume, 1993; Previc, 1998). However, lower visual field advantages have been observed in short duration (200ms) motion and orientation discrimination tasks (Rezec & Dobkins, 2004). Rezec and Dobkins propose that individuals do not evenly distribute their attention across the visual field; instead, there is a bias to the lower visual field (or inferior visual field – their words), which they describe in the attentional weighting hypothesis.

Biased sample, biased results

Many models of brain organization and cognition, including those highlighting lateralized differences, are based on a subpopulation of Western participants. As Eviatar (2000) notes, this may not account for other possible organization of the brain – as reading direction can affect performance on non-linguistic tasks (Chokron & De Agostini, 2000; Fagard & Dahmen, 2003; Ishii et al. 2011). The role of an individual's first language (native reading direction) in cognitive tasks is not agreed upon. The directions that text is read and written in, and subsequent scanning direction, are thought to be a factor in differences observed in spatial tasks (Chokron & Imbert, 1993; Fagard & Dahmen, 2003). The hypothesis that lateral biases in cognitive tasks exist between different reading direction groups is disputed, as several studies have not found scanning habits to influence biases. Nicholls and Roberts (2002) and Barrett et al. (2000) did not find biases to differ between reading direction groups on visual-spatial tasks. Nicholls and Roberts failed to find opposite biases between English and Hebrew participants on greyscale and line bisection tasks. Both English and Hebrew readers displayed leftward biases; with English readers exhibiting greater leftward biases on the greyscales task and Hebrew readers exhibiting greater leftward biases on the line bisection task. Using line bisection, drawing and spatial-syntactic tasks, Barrett et al. found no influence of reading direction with vertical left-to-right and vertical right-to-left Korean readers. Participants in both groups showed no bias when drawing out the action of a sentence read aloud to them (the spatial-syntactic task), but both groups demonstrated a leftward bias when asked to make drawings of a house, tree, and person on three separate pieces of paper, and in line bisection.

Measures of attention known to elicit lateral biases, like line bisection, greyscales and aesthetic preference have been more closely examined using a more culturally representative population by including participants with reading directions other than left-to-right. Tasks using target finding have not been scrutinized in the same way, and neither have assumptions of lighting direction – with the exception of a recent study by Smith and Elias (2013). Through the current set of experiments we aim to draw attention to differences in light source perception and target finding between groups of individuals with different native reading directions.

Predictions

The unifying theme of the studies conducted was to assess potential perceptual differences between right-to-left and left-to-right readers using stimuli devoid of 3D cues, other than lighting and shading, in a target finding task in which targets either popped out or sunk in, depending on lighting angle. Differences in lateral biases while performing varied cognitive tasks (Chokron & Imbert, 1993; Morikawa & McBeath, 1992; Smith & Elias, 2013) and contrasting scanning habits between groups with different native languages (Abed, 1991; Pollatsek et al., 1981), indicate that target identification duration times and scanning distributions in quadrants between left-to-right and right-to-left readers will be different from one another. We have not set out to question existing models that propose common neural and cognitive processes in all humans, but rather to stress the importance of thoroughly testing phenomena using a representative, culturally variable population. The assumption that findings are generalizable, even though data supporting them are only from college aged Western individuals, needs to be critically examined while the universality of the conclusions questioned (Segall, Campbell, & Herskovit, 1968).

Following findings of upper-left lighting advantages in target finding (McManus et al., 2004; Sun & Perona, 1998), upper-left lighting should facilitate shorter duration times for left-to-right readers. As there is little existing literature pertaining to right-to-left readers' behaviour when presented with ambiguously lit stimuli, our conservative prediction is that shorter durations for target identification will not occur under upper-left lighting conditions, and indeed, decreased average durations for finding a target may occur under upper-right lighting conditions. The hypothesized unequal distribution of attention to the left side of space outlined in pseudoneglect theory suggests that left-to-right readers' average duration times for target identification in the left side of space will be shorter than for targets in the right. Further, results from past target identification studies find upper visual field advantages in free-viewing target-finding tasks (Previc, 1998); therefore left-to-right readers' shortest durations for finding a target are predicted to be for those located in the upper-left quadrant. Our predictions for right-to-left readers follow from evidence that suggest learning to read right-to-left shifts biases away from the left, resulting in weaker leftward biases. Depending on other factors, as identified by Jewell and McCourt (2000), rightward biases may even be observed. Right-to-left readers are therefore predicted to show a weaker upper-left, or even slight upper-right, bias for shortest durations based on target location.

Longer durations are predicted for upper-left quadrants for left-to-right readers, while right-to-left readers are predicted to exhibit longer durations for upper-right quadrants. These hypotheses follow from the assertion made by Abed (1991) and Chokron and Imbert (1993) that non-directional stimuli, in this case target finding arrays, can be visually explored in the same way as directional stimuli.

CHAPTER 2

SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: LEFT-TO-RIGHT READERS

The data for chapter 2 was collected in the fall of 2011 at the University of Saskatchewan. Target finding, lighting biases, and eye movements have been examined exclusively from one another in past studies, but the purpose of the research presented here is integrative in nature. Rather than being solely interested in the spatial location or illumination of a target, we sought to identify interactions between these variables as well as with scanning distributions.

The perception of three-dimensions (3D) when viewing an object is a complex visual process; accomplished by assumptions made by the brain about the object and by environmental cues (Mamassian & Goutcher, 2001; Ramachandran, 1988). Observations by Rittenhouse (1786) about the reversal of the depressions and ridges on a brick (by inverting lighting direction with a mirror) are some of the first about lighting and shading. Shading is one technique used to give depth to two-dimensional objects that can be manipulated to alter our visual perception.

The human visual system resolves the presentation of ambiguously lit stimuli with prior assumptions about the location of the light source and the shape of the object (Langer & Bulthoff, 2001; Mamassian & Goutcher, 2001; Gerardin et al., 2007). Ramachandran (1988) and Kleffner and Ramachandran (1992) have proposed that the visual system perceives three dimensions by assuming a single, overhead light source. Additionally, convexity is assumed rather than concavity – consistent with the light from above prior – as light from above creates a convex image (Elias & Robinson, 2005; Langer & Bulthoff, 2001; Mamassian & Goutcher, 2001). Lighting differences in 3D perception have been examined in experiments using egg and dimple stimuli (Kleffner & Ramachandran, 1992), stimuli with raised and depressed undulating lines (Mamassian & Goutcher, 2001; Mamassian et al., 2003), the Polo Mint stimulus (Gerardin et al., 2007), and textured half cylinder stimuli (Langer & Bulthoff, 2001). But as Adams et al. (2004) have shown, these prior assumptions are not rigid, and can change using haptic training.

Using egg and dimple stimuli, Sun and Perona (1998) found a leftward lighting bias in a visual search task, as quicker reaction times where observed when distractors appeared to be lit from the above-left. Sun and Perona suggest that top left lighting may have higher perceptual value, as their sample of 225 master paintings from across varied schools and periods, displayed a predominate upper-left light source. Thomas et al. (2008) looked at full-page magazine advertisements and found more to be left-lit than centrally or right-lit. Hutchison et al. (2011) found advertisements to be preferred when illuminated from the left, as leftward-lit advertisements received more positive overall ratings and higher ratings for feeling toward brand name and toward advertisement.

Mamassian et al. (2003) suggest that brain activity mirrors these behavioural biases. Using the aforementioned lined stimuli, Mamassian et al. report that the N2 component of event-related potentials in the occipital, temporal, and parietal regions was modulated by stimulus orientation (lighting directions). Explanations for the occurrence of a leftward lighting bias – rather than a rightward, or a lack of bias – are varied. Scanning biases theories propose that scanning habits (tied to reading direction) influence attention (Abed, 1991; Morikawa & McBeath, 1992). Barrett et al. (2002) and Nicholls and Roberts (2002) have not found scanning habits to influence attention, suggesting that biases in visual attention are because of superior right hemisphere processing of spatial information and attention (Davidoff, 1975; Nicholls et al., 1999).

Similar to asymmetries in perceiving light, left/right disparities of spatial attention occur. An overestimation of the left side of space, resulting in left of centre bisections, is well documented in Jewell and McCourt's (2000) line bisection meta-analysis. Similar effects have been observed with blind individuals, as Catteno et al. (2011) reported greater leftward errors on a haptic line bisection task among blind individuals than those of blindfolded sighted individuals. Additionally, judgments about equivalent stimuli in the left side of space are made more quickly as larger, more numerous, and brighter than those in the right side of space (Nicholls et al., 1999). Because of similarities to clinical neglect, this leftward attentional bias among neurologically normal individuals is commonly referred to as pseudoneglect (Bowers & Heilman, 1980). The nature of the relationship (or, if such a relationship exists at all) between the leftward lighting bias and pseudoneglect (and other lateral asymmetries of perception) is not known.

In addition to lateral differences, attentional inequalities between upper and lower visual fields have been found (Thomas & Elias, 2011). As with lighting biases, explanations for visual field advantages, as well as in which visual field advantages lie, are quite varied and often contradictory of one another. Typically, advantages in the lower visual field include performance on contrast sensitivity, motion, and visual acuity; while local processing, categorical judgments, and visual search are superiorly processed in the upper visual field (Karim & Kojima, 2010; Thomas & Elias, 2011). Previc (1990) suggests a model in which visual field advantages rely on where in space, extrapersonal or peripersonal, a task is carried out. Accordingly, a target finding task occurs in focal extrapersonal space (FcE) and yields upper visual field advantages (Previc & Blume, 1993; Previc, 1998). However, lower visual field advantages have been observed in short duration (200 msec.) motion and orientation discrimination tasks (Rezec & Dobkins, 2004).

Rezec and Dobkins propose that attention is not evenly distributed across the visual field; instead, there is a bias to the lower visual field, which they describe in the attentional weighting hypothesis.

The current study used a shape from shading target finding paradigm, in which targets were determined by perceived lighting direction. Egg and dimple stimuli were presented in a 4 by 4 grid, with lighting direction and target location varying randomly in each trial. Eye-tracking procedures were implemented to record scanning durations of the upper-left quadrant, lower-left quadrant, upper-right quadrant, and lower-right quadrant. Predictions based on lighting direction are presented first and should be understood as somewhat separate from target location and quadrant predictions. Shorter duration times for target identification were expected for trials in which the array was illuminated from the left, consistent with observations by Sun and Perona (1998). Past target finding task studies tasks have produced inconsistent results, with some finding upper visual field advantages (Previc & Blume, 1993), others finding lower visual field advantages (Rezec & Dobkins, 2004), while others identified right visual field advantages (Previc & Blume, 1993; Yund, Effron, & Nichols, 1990). To further confound matters, pseudoneglect literature suggests an overestimation of the left side of space (Nicholls et al., 1999), which could influence participant performance on our target finding task. Following these mixed outcomes, predictions for shortest duration times for target location and longest duration times for quadrant were based on scanning biases theories (Abed, 1991; Morikawa & McBeath, 1992). Predictions follow scanning bias theories that suggest participants should spend greater amounts of time examining the left side of images and finding targets quicker when located there. Participants are predicted to examine stimuli in manner similar to reading, with more fixations allocated to the left side of space. Therefore, shortest durations were predicted for trials where the target was located in the upper-left quadrant, and longest durations were predicted to be in the upper-left quadrant. Although not a formal prediction, average durations in each quadrant were thought to increase when the target was located there. This was a manipulation check to see if participants were indeed searching for the target, and indicating when it was found, as instructed.

Method

The Research Ethics Board at the University of Saskatchewan approved this study (Appendix A).

Participants

Sixty-eight University of Saskatchewan undergraduate students received course credit for participation. Data was not collected from 8 participants due to eye-tracking difficulty (glasses, dark eye make-up) or experimenter error. Two participants' data sets did not meet minimum criteria for usability. The remaining 58 (18 male) participants had an average age of 20.2 (SD=3.6) and were right handed (3 left handed). Table 1 provides a breakdown of participants' first languages.

Direction	Language	Number of participants
Left-to-Right	Bengali	1
	Chinese	5
	English	44
	Filipino	1
	Punjabi	1
	Oriya	1
	French	1
	Korean	1
Right-to-Left	Assyrian	1
	Urdu	2

Table 1. Participants' first languages including directionality of script.

Materials

A SensoMotoric Instruments (SMI) Remote Eye-Tracking Device (RED II) recorded participant eye movements at a frequency of 60 Hz. Eye movement data was processed by iView (3.1) software running on a custom built workstation by SMI with an 800 MHz Pentium 3 processor and 256 MB of RAM. Presentation of stimuli was on a 1024x768 resolution 19-inch LCD display by E-prime (v.1.2) running on a 1.8 GHz Pentium 4 processor computer, linked by serial connection to the SMI workstation. A chin rest, approximately 700mm from the computer display, was used to help reduce movement.

Stimuli were images of a 4x4 array of shaded spheres with one target sphere (Appendix B), loosely based on other target finding experiments using illuminated spheres (Sun & Perona, 1998; McManus et al., 2004). Each image consisted of 15 spheres with the same lighting angle and one odd one out with an opposite lighting angle, e.g. 15 spheres at +45 degrees and one at -135 degrees. Spheres could be illuminated from 16 different angles, ±22.5 degrees, ±45 degrees, ±67.5 degrees, ±90 degrees, ±112.5 degrees, ±135 degrees, ±157.5 degrees, 0 degrees or 180 degrees (negative leftward) with the target in 1 of 16 locations, resulting in 256 test trials. Test trials were randomized and preceded by a 9-point calibration exercise and 24 practice trials. Handedness and footedness effects were accounted for as potential co-variates using the Waterloo Footedness Questionnaire–Revised developed by Elias, Bryden, and Bulman-Fleming (1998). Basic demographics, including first language and occurrences of sinistral relatives were collected in the questionnaire (Appendix C).

Procedure

Participants were welcomed and seated at a desk in a small windowless room with standard overhead fluorescent lighting. A brief explanation of the consent form (Appendix D) and the questionnaire (Elias et al., 1998) was given, followed by time to ask questions and complete the forms. After informed consent was given participants positioned themselves comfortably in the chair and chin rest so they were centered to the computer display. Verbal and on-screen instructions to search for the odd one out and press space bar as soon as it was found were given, as well as another opportunity to ask questions. Following each trial, a fixation cross appeared for 1000 msec. After completing the first block of 256 trials, participants took a short rest, and when possible, completed the same 256 trials again. On average, participants took no longer than 35 minutes to complete the experiment. Before leaving, participants were given a debriefing form (Appendix E) explaining the experiment and the rationale behind it, and were thanked for their participation.

Coding and Analysis

Eye movement data from iView was converted to plain text and imported to iLab (Gitelman, 2002), where an analysis of the duration of time spent examining the upper-left quadrant, lower-left quadrant, upper-right quadrant, and lower-right quadrant was carried out. Lighting direction (of the array) and target location were coded for using the same quadrant divisions. Trials with stimuli that had a light source at 0,180, or 90 degrees were eliminated from the final analysis, resulting in 192 test trials. Participants' trials were aggregated and structured so that every combination of lighting direction (4), target location (4), and quadrant (4) was investigated. A 4x4x4 repeated measures analysis of variance (ANOVA) with within-subjects factors of lighting direction, target location, and quadrant was carried out to look for lighting conditions and target locations that facilitated shortest average durations for target identification and the quadrant in which the longest average durations occurred.

Results

Main effects of lighting direction, $F(3, 171) = 72.88$, $p < 0.001$, $\eta p^2 = 0.561$, and target location, $F(3, 171) = 17.68$, $p < 0.001$, $\eta p^2 = 0.237$, were found for above-left lighting conditions, and when targets were located in the upper-left quadrant, respectively, as predicted. Contrary to predictions, a main effect of quadrant was observed, with the greatest amount of time spent examining the upper-right quadrant, $F(3, 171) = 17.84$, $p < 0.001$, $\eta p^2 = 0.238$. Main effects are shown in figure 1.

The three-way interaction between lighting direction, target location, and quadrant was significant, $F(27, 1539) = 19.16$, $p < 0.001$, $\eta p^2 = 0.252$. To better understand this complex interaction, two-way interactions between lighting direction and target location, lighting direction and quadrant, and target location and quadrant were examined. Additionally, a means table from the three-way interaction is provided for further clarification (Table 2).

The interaction between lighting direction and target location was significant, $F(9, 513) = 5.18$, $p < 0.001$, $\eta p^2 = 0.083$ (Figure 2). Post hoc paired-samples t-tests were carried out to explore the possibility that overall shortest durations for target identification resulted from upper-left target locations and upper-left lighting directions. Indeed, the combination of upper-left target location and upper-left lighting were found to elicit significantly shorter durations for target identification than any other condition. A significant interaction between lighting direction and quadrant, $F(9, 513) = 32.14$, $p < 0.001$, $\eta p^2 = 0.361$, was also observed (Figure 3). To test the predicted relationship between upper-left lighting increasing average durations in the upper-left quadrant, post hoc paired-samples t-tests were carried out. Results did not support the predicted longer durations. The interaction between target location and quadrant, $F(9, 513) = 197.76$, $p < 0.001$, $\eta p^2 = 0.776$, was also found to be significant (Figure 4). Post hoc paired-samples t-tests examining the combination of the upper-left quadrant and the target in that same quadrant with other quadrant/target combinations found the upper-left-upper-left combination to elicit significantly longer durations than others, with the exception of the combination of upper-right quadrant and the target located in that same quadrant ($t(57) = 0.308$, $p = 0.760$).

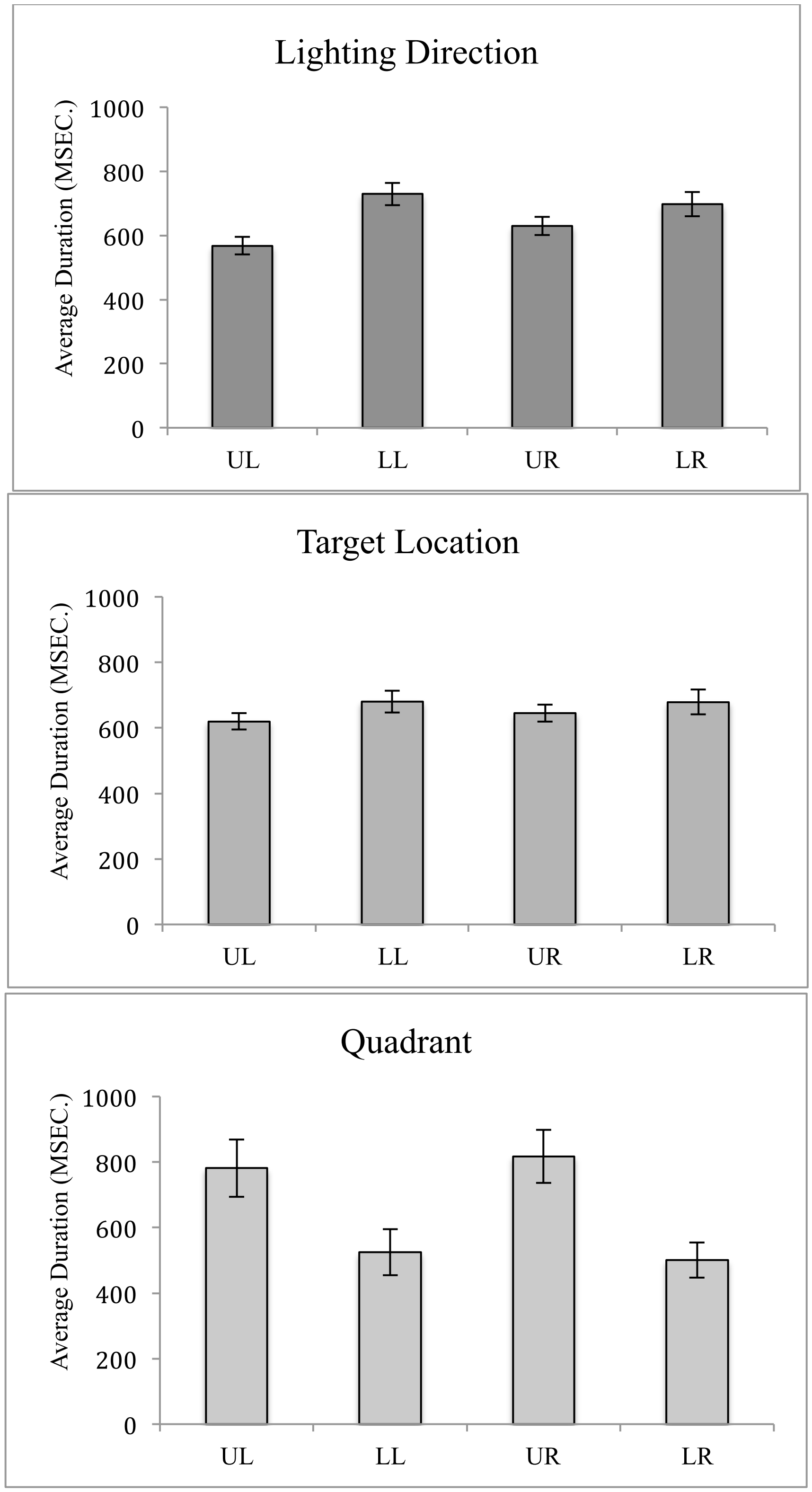


Figure 1. Main effects of lighting direction, target location, and quadrant. Shorter durations for lighting direction and target location indicate faster target identifications.

Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

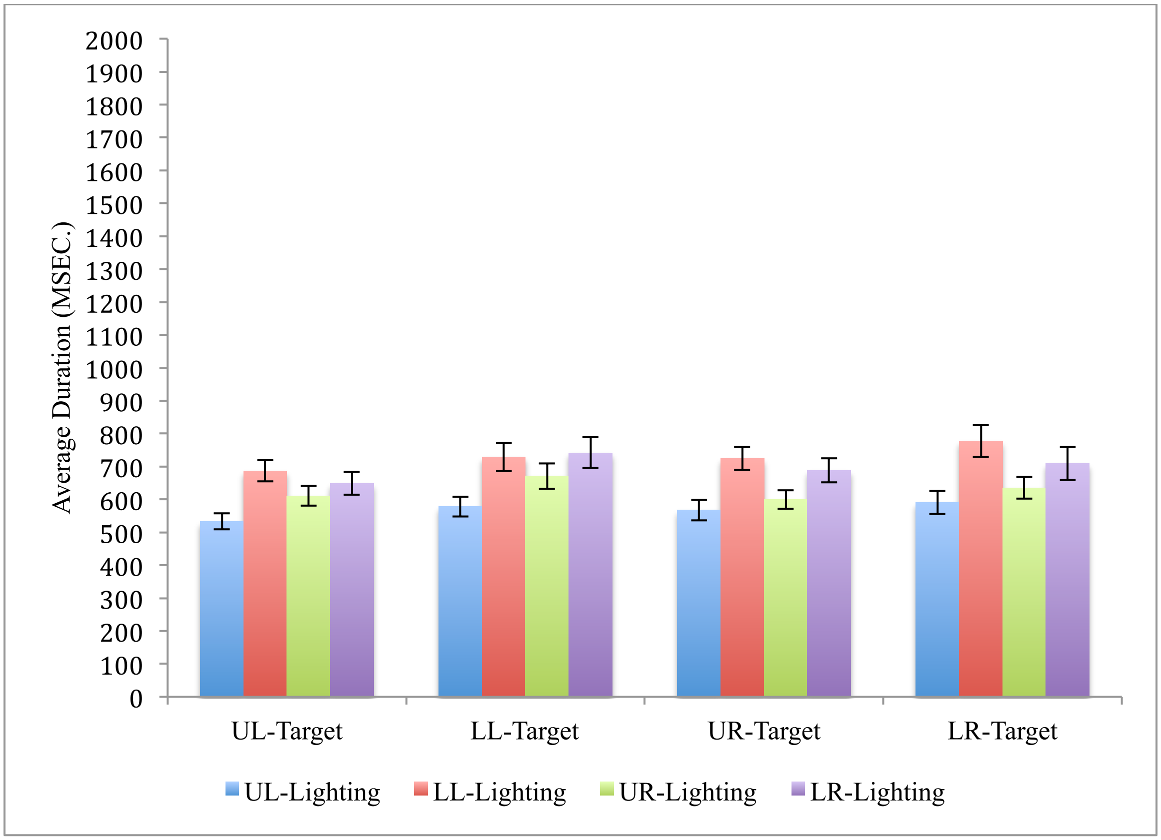


Figure 2. Interaction between lighting direction and target location. Shorter durations indicate faster target identifications. Error bars represent 95% confidence intervals.

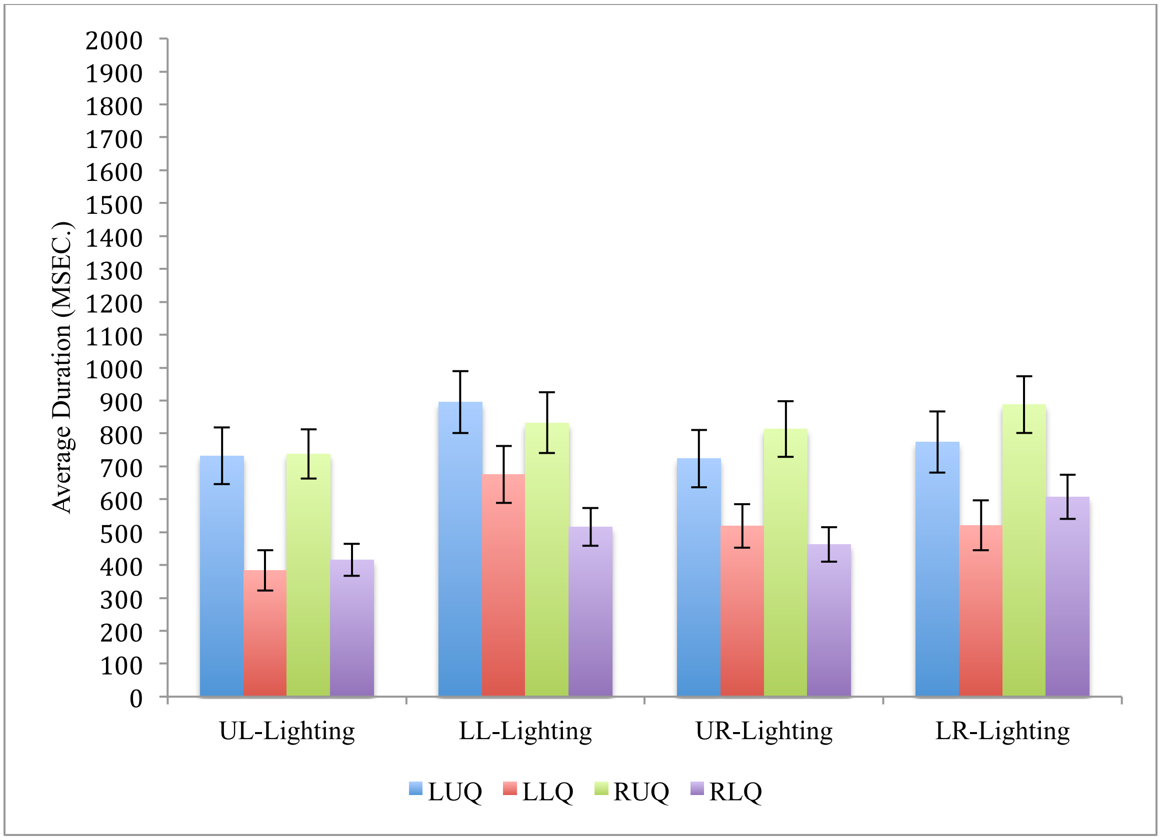


Figure 3. Interaction between lighting direction and quadrant. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

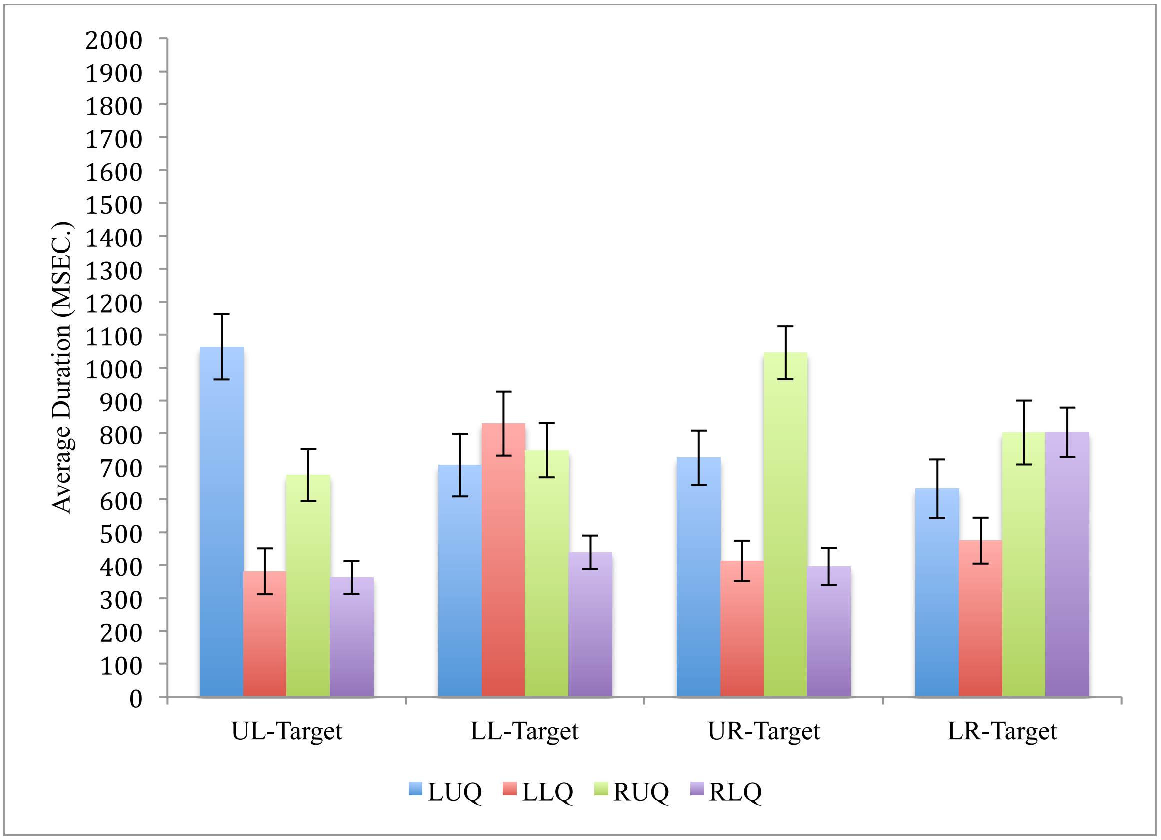


Figure 4. Interaction between target location and quadrant. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

		UL-Target	LL-Target	UR-Target	LR-Target
UL-Lighting	LUQ	1038.619	718.537	628.928	542.655
	LLQ	297.099	582.63	341.522	314.382
	RUQ	521.391	650.745	967.895	811.575
	RLQ	273.971	362.645	332.09	695.145
LL-Lighting	LUQ	1139.524	777.076	958.258	706.501
	LLQ	498.745	973.801	505.35	722.033
	RUQ	710.848	740.653	1053.422	823.634
	RLQ	397.739	422.887	382.323	859.617
UR-Lighting	LUQ	1020.691	623.386	585.893	664.043
	LLQ	340.472	875.497	454.017	404.308
	RUQ	733.721	748.785	1062.028	707.861
	RLQ	348.613	437.412	296.581	766.175
LR-Lighting	LUQ	1051.194	695.319	732.463	615.932
	LLQ	386.403	887.127	351.716	456.582
	RUQ	730.139	854.319	1098.237	869.504
	RLQ	428.363	530.757	572.039	896.401

Table 2. Means table from the interaction between lighting direction, target location, and quadrant.

Discussion

Amount of time taken to identify a target based on target spatial location *or* illumination of the array has been the dependent variable of interest in past visual search paradigms (Previc & Blume, 1993; Sun & Perona, 1998), but in the current study we compared shortest durations for target identification based on target location *and* array illumination, and longest durations for the upper-left, lower-left, upper-right, and lower-right quadrants. This comprehensive approach of integrating a direct measure of visual attention, eye-tracking, with target identification analyses for spatial location and lighting direction of targets, created through shape from shading, is novel.

As predicted, the shortest average durations for identifying a target occurred when illumination was from the upper-left and when targets were located in the upper-left quadrant. Our observations are consistent with previous outcomes of studies examining lateral differences in illumination (Elias & Robinson, 2005; Sun & Perona, 1998). Comparing light from above with light from below, average durations for identifying a target were less when light was from above, supporting Kleffner and Ramachandran's (1992) assertion that concave targets are easier to identify against backgrounds of convex distractors.

The main effect of shortest durations for identifying a target in the upper-left quadrant supports predictions, and runs somewhat contrary to past target finding studies, which found a secondary right visual field (after a primary upper visual field) advantage for target identification (Previc & Blume, 1993). As well, Christman and Niebauer's (1997) hypothesized association between the upper and right visual fields, observed in other measures of visual attention, was not supported. Results support a leftward attentional bias, as it took less time to identify targets in the left side of space than targets in the right side of space. The combination of targets in the upper-left quadrant and upper-left lighting, and the significant interaction between them, further support pseudoneglect theory. Additionally, the paired-samples t-tests indicating that the upper-left/upper-left combination elicited the shortest durations for target identification continues to allow for the potential relationship between leftward biases of spatial attention and leftward biases of lighting to exist.

One aim of the current study was to explore visual field differences of left-to-right readers. Eye-tracking methods have been reliably applied to directly measure visual attention, in both the line bisection and greyscales tasks, confirming previously observed visual field asymmetries (Thomas, Loetscher, & Nicholls, 2012; Thomas & Elias, 2011). Results from the current study promote the validity of eye-tracking as a direct measure of attention as more time was spent inspecting the upper visual fields in the shape from shading target finding task, supporting previous research. The hypothesis that the longest durations would occur in the upper-left quadrant was not supported. Quadrant analysis revealed a significant main effect of longer durations for the upper-right quadrant. This analysis did not provide a particularly clear picture of how attention is laterally allocated during target-finding, however it is clear post hoc pairwise comparisons that greater durations of time are spent exploring the upper-left and upper-right quadrants. The post hoc paired samples t-tests between quadrant and target location further explains the issue, participants examined the upper-left quadrant when the target was located there significantly more than any other combination of quadrant and target location, except for the upper-right quadrant/upper-right target. This illustrates greater differences between the upper and lower quadrants, rather than later quadrants, consistent with past target-finding studies finding shorter target identification times for targets located in the upper visual field (Previc & Blume, 1993).

Advantages in processing stimuli in the lower visual field are more often found in tasks in peripersonal space, while tasks in extrapersonal space are biased to the upper visual field (Previc, 1998). The upper visual field advantage observed in our visual search task supports this categorization of an extrapersonal space task. More specifically, visual search tasks, including the current study, supposedly occur in the FcE – the area of high visual acuity without a fixed depth (ranging from 10-20cm to 6m) in the central 30 degrees of the visual field (Honda & Findlay, 1992; Previc, 1990).

A means analysis of target location and quadrant interaction reveals that participants spent greater amounts of time examining a quadrant when it encompassed the target, in line with informal predictions. This indicates that participants completed the task as instructed, pressing the space bar and advancing to the next trial only after finding the target.

As our results show, interactions occur between where the target is in visual space, how the array is illuminated, and where attention is visually directed. The complexity of the visual attention system, the vast differences in theories attempting to explain it's functioning (Bowers & Heilman, 1980; Chokron & Imbert, 1993; Davidoff, 1975; Nicholls et al., 1999; Previc, 1998), and the varied outcomes pertaining to behaviour and performance found within each theory, must be taken into account when considering results from the current study.

Our attempt to parse out lighting direction and spatial location results from a single task has left room for future studies to improve and expand findings, by using simpler stimuli or different procedures. Presentation time of stimuli and fixation slides in between stimuli presentations can also be improved upon. In this study we did not build any measures into the experiment, other than verbal instruction, to ensure participants actually refocused on the centre fixation cross between each trial. Future studies could ensure more precise eye-tracking data through a guaranteed central fixation between each trial. The current study used a free viewing methodology, that is, participants controlled when slides changed. Future studies using controlled presentation time of stimuli slides may elicit interesting differences in eye movement data, and even opposite lower visual field advantages, as has been reported by Rezec and Dobkins (2004) when stimuli presentation time is decreased. Adding an additional component to measure accuracy of target identification could be implemented in future research.

CHAPTER 3

SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: LEFT-TO-RIGHT & RIGHT-TO-LEFT READERS

Data for chapter 3 was collected at the University of Saskatchewan in the spring of 2012. As in study 1, we attempted to assess differences in illumination of target finding arrays and target positions, while recording eye movements. We were interested in the possibility that one's native reading direction may influence conditions that facilitate quickest target identification. Additionally, we were interested to see if scanning distributions varied between left-to-right and right-to-left readers when completing a shape from shading target finding task. This study was the first to be carried out using iViewX software and the Sensomotoric RED-4 camera. This new technology allowed us to remove participant input for indicating target identification by recording the amount of time taken to find a target based on eye fixations.

Pseudoneglect is a phenomenon among the neurologically normal population where a leftward attentional bias occurs which mirrors neurologically damaged – often, right parietal cortex – hemi-spatial neglect (neglect) patients, who neglect the left side of space (Bowers & Heilman, 1980; Bradshaw, Nettleton, Nathan, &Wilson, 1985). When asked to place a marker at the middle of a line neglect patients will tend to place the marker to the right of true centre, while a reversal among normals occurs as they will bisect the line consistently to the left of centre (Bowers & Heilman, 1980; Jewell & McCourt, 2000). Some have failed to reproduce leftward bisections (Manning et al., 1990) while others have shown the leftward bias in variations of classical line bisection. In a forced choice tachistoscopic line bisection, where participants must decide if a pre-bisected line has a leftward or rightward bisection, McCourt (2001) found leftward errors in 91% of cases. Mattingley et al. (1994) report similar spatial biases in neglect patients and controls in the greyscales task and when examining chimeric faces. With neutral/smiling chimeric faces and equiluminant rectangles, neglect patients showed a rightward bias and the control group demonstrated the opposite leftward bias when asked to determine the happier face and which rectangle is darker. It appears that this leftward attentional bias does not depend on any specific feature as Nicholls et al. (1999) demonstrated the leftward attentional bias irrespective of target – which is lighter/darker, more/less numerous, or bigger/smaller – in the greyscales, star, and shape tasks, respectively.

Pseudoneglect effects in line bisection are not limited to visual space. Using horizontal, vertical, and radial haptic line bisection Cattaneo et al. (2011) found neurologically normal blind folded sighted participants and blind participants to have a leftward bias in the horizontal condition. Additionally, sighted individuals were found to have downward and proximal biases of the vertical and radial conditions. Pseudoneglect is not limited by species either, as Regolin (2006) demonstrated with 9-day-old chicks. Using an adapted line bisection task, birds were trained to peck at the centre bead. Side pecks were fewer than central pecks, but mistakes that were made were significantly leftward.

Nicholls et al. (2008) as well as Thomas et al. (2009) report similar pseudoneglect effects during collision tasks. When the left side of space is over represented in collision tasks, as it is in line bisection, the result is more collisions with the right side of the body. Nicholls et al. reported more collisions on the right than the left when passing through a doorway while dialing a phone with the either the left, right, or both hands. Using a virtual environment Thomas et al. found more rightward collisions when routes were followed in the upper visual field or in the central condition by left handers only; left side collisions were only observed in the lower visual field condition and overall there were more collisions in the upper visual field than the lower visual field or central conditions.

Explanations for pseudoneglect are varied. Some propose that leftward biases result, at least in part, from the right hemisphere's superior processing of spatial information (Chokron & Imbert, 2003; Nicholls & Roberts, 2002). Handedness, age, sex, hand used to perform the task, and scanning direction all appear to effect the severity, or even direction, of pseudoneglect (Jewell & McCourt, 2000). When scanning habits are considered, evidence both for (Brodie & Pettigrew, 1996; Fagard & Dahmen, 2003) and against (Barrett et al., 2000; Nicholls & Roberts, 2002) the shift from left to right on tasks measuring pseudoneglect such as line bisection, is found. Fagard and Dahmen (2003) provide strong evidence for the influence that language can have on spatial biases by looking at children before and after learning to read and write. Fagard and Dahmen compared French (left-to-right reading) and Tunisian (right-to-left reading) children aged 5, 7, and 9 across three measures: line bisection, circle drawing, and dot filling. French children made greater leftward line bisections than Tunisian children with differences becoming significant, with both the left and right hand, by age nine. From age 7 and on, Tunisian children followed a pattern of clockwise drawing while counter clockwise movements were found in French children. Again at age 7, significant differences arose between the two groups on the dot-filling task as French children were able to fill in more dots moving left to right, and Tunisian children filled more dots in moving right to left (Fagard & Dahmen 2003).

Several studies have found null results when examining the influence of scanning habits on lateral biases. Nicholls and Roberts (2002) did not find biases to differ between reading direction groups on visual-spatial tasks, as both English and Hebrew readers displayed leftward biases; with English readers exhibiting greater leftward biases on the greyscales task and Hebrew readers exhibiting greater leftward biases on the line bisection task. Using line bisection, drawing, and spatial-syntactic tasks, Barrett et al. (2000) found no influence of reading direction with vertical left-to-right and vertical right-to-left Korean readers. Participants in both groups showed no bias when drawing out the action of a sentence read aloud to them (the spatial-syntactic task), but both groups demonstrated a leftward bias when asked to make drawings of a house, tree, and person on three separate pieces of paper, and in line bisection.

Cross-cultural research provides empirical data supporting visuo-spatial differences between groups reading in different directions. With the exception of studies mindful of cultural population variability and the aforementioned studies, research in the behavioural sciences is for the most part based solely off of data from undergraduate students at Western universities (Henrich et al., 2010). As such, many models of brain organization and cognition are based on this subpopulation lacking variability, which, as Eviatar (2000) notes, may not account for other possible organization of the brain – as reading direction can affect performance on non-linguistic tasks (Abed, 1991).

The leftward lighting bias is one such phenomenon that has not received the same population variability scrutinizing that other attentional biases, like line bisection (Chokron & Imbert, 1993), grey scales (Nicholls & Roberts, 2002), and aesthetic preference (Ishii et al., 2011) have received. In their study using shape from shading stimuli in a target finding task, Sun and Perona (1998) describe the leftward lighting bias as the preferred lighting direction for the quickest identification of a target among a field of distractors. Research of the preference for left lighting over right or central lighting evolved out of studies examining light perception first described by Rittenhouse (1786), and subsequently by Ramachandran (1988) and Connor (2001). Rittenhouse with bricks from the hearth, and Ramachandran and Connor with shaded spheres, discuss shape from shading. Three-dimensional illusions created when objects are lit from above or below versus lit from angles approaching 90 degrees, have lead researchers, such as Ramachandran as well as Connor, to postulate that the visual system is adapted for a single light source originating from above, in large part because of our solar system with one sun. Continuing research with shape from shading stimuli, artwork, and advertisements has found that leftward lighting is robustly preferred (Elias & Robinson, 2005; Hutchison et al., 2011; Mamassian & Goutcher, 2001; Sun & Perona, 1998; Thomas et al., 2008)

Ever since Metzger's early observation of light from the left and right not being perceptually equivalent (Sun & Perona, 1998), no investigation has been carried out pertaining to the potential influence that scanning direction – influenced by reading direction – could have on this phenomenon. Given the reversal of biases seen in line bisection tasks (Chokron & Imbert, 1993; Fagard & Dahmen, 2003), aesthetic judgments (Chokron & de Agostini, 2000; Ishii et al., 2011), and dot filling and clock drawing tasks (Fagard & Dahmen, 2003) when the native reading direction of the participants is considered, we propose scanning duration and target identification differences between left-to-right and right-to-left readers on a shape from shading target finding task.

As past research finding leftward biases has tended to use samples of exclusively left-to-right readers, we predict the data from right-to-left readers to show weaker leftward biases, and in some cases maybe even display rightward biases, as we hypothesize that native reading direction influences light source perception, scanning distributions, and target identification. Although not a formal prediction, average durations in each quadrant were thought to increase when the target was located there. This was a manipulation check to see if participants were indeed searching for the target, and indicating when it was found, as instructed.

Left-to-right readers

Shorter average duration times for target identification were expected for trials in which the array was illuminated from the above left, similar to observations by Sun and Perona (1998) and McManus et al. (2004). Expectations for shortest duration times for target identification based on target location were predicted for targets located in the upper-left quadrant. This prediction is made reservedly, given the variance in results between past studies (Previc & Blume, 1993; Rezec & Dobkins, 2004; Yund et al., 1990) and the potential differences introduced by using targets that only appear once shape from shading information has been extracted by the participant – which may tax attentional resource more than other target finding tasks. Longest durations are expected to be longest in the upper-left quadrant across all target location and lighting conditions, in line with scanning biases theory (Abed, 1991; Chokron & Imbert, 1993; Morikawa & McBeath, 1992). Target identification based on spatial location and duration times of quadrant should work together, with shortest durations for target identification occurring in the quadrant where the longest durations occur.

Right-to-left readers

We predict that target identification will not be facilitated to the same extent by leftward lighting for right-to-left readers, as it should be for left-to-right readers. Further, right lighting may actually decrease target identification duration times for right-to-left readers. Shortest target identification duration times are conservatively predicted to be in the upper quadrants, with a lateral prediction of the upper-right quadrant. Longest durations are also predicted to be biased towards upper quadrants, with the longest durations predicted to be for the upper-right quadrant of the arrays, following from scanning biases theory (Abed, 1991; Chokron & Imbert, 1993; Morikawa & McBeath, 1992). As for left-to-right readers, target identification based on spatial location and duration times of quadrant should work together, with shortest durations for target identification occurring in the quadrant where the longest durations occur.

Method

The Research Ethics Board at the University of Saskatchewan approved this study (Appendix F).

Participants

Thirty left-to-right reading and 32 right-to-left reading participants took part in the study. Data was not collected from one right-to-left participant and 2 left-to-right participants because of eye tracking difficulties. The average age of the 28 (9 male) remaining left-to-right reading participants was 22 years (SD=5.3) 2 of which were left-handed. Of the 31 (14 female) remaining right-to-left readers 4 were left-handed with an average age of 29.6 (SD=5.8). All right-to-left readers were bilingual, with their time spent in Canada varying from a few months to a few years. Those recruited through the psychology participant pool received study credit and all others received remuneration. Table 3 provides a breakdown of participants' first languages.

Direction	Language	Number of Participants
Left-to-Right	Afrikaans	1
	English	27
Right-to-Left	Arabic	1
	Azeri (Farsi)	1
	Persian (Farsi)	26
	Urdu	3

Table 3. Participants' first languages including directionality of script.

Materials

A SensoMotoric Instruments (SMI) Remote Eye Tracking Device (RED 4) recorded participant eye movements at a frequency of 60 Hz. Eye data was passed through to iView X (2.7) operating on an SMI custom built PC with a 2.4 GHz Intel CPU and a 580 MHz Nvidia

GeForce 9300M GS graphics card. Presentation of stimuli was done by Experiment Center (3.0) on a 1280x1024 resolution computer monitor.

Stimuli were the same shaded spheres used in experiment 1 (Appendix B), presented in a 4x4 array consisting of 15 spheres with the same lighting angle and one odd one out with an opposite lighting angle, e.g. 15 spheres at +45 degrees and one at -135 degrees. The stimuli were loosely based on other target finding experiments using illuminated spheres (Sun & Perona, 1998; McManus et al., 2004). In the array of 16 spheres the target occurred in each of the 14 lighting angles in each of the 16 positions, making for 224 test trails. Test trials were randomized and preceded by a calibration exercise and 4 practice trials, as in study 1 & 2. Handedness and footedness effects as potential co-variates were accounted for using the Waterloo Footedness Questionnaire–Revised developed by Elias et al. (1998) (Appendix C). Basic demographics, including first language, were collected in the questionnaire.

Procedure

Participants were welcomed and seated at a desk in a small windowless room with standard overhead fluorescent lighting. A brief explanation of the consent form (Appendix G) and the questionnaire (Elias et al., 1998) was given, followed by time to ask questions and complete the forms. After informed consent was obtained, participants positioned themselves comfortably in the chair while verbal and on-screen instructions were given to find the odd one out for each array of spheres, and when found to continue to fixate on it. The experiment was programmed in such a way that no input was required from participants. When the target sphere was found and fixated on for a continuous 750 msec. the slide would automatically change to a central fixation cross for 500 msec. and then to the next array of spheres. Before leaving, participants were given a debriefing form (Appendix H) explaining the experiment and the rationale behind it, and were thanked for their participation.

Coding and Analysis

Eye movement data from iView was imported to iLab (Gitelman, 2002), where an analysis of the duration of time spent examining the upper-left quadrant, lower-left quadrant, upper-right quadrant, and lower-right quadrant was carried out. Lighting direction (of the array) and target location were coded for using the same quadrant divisions. Trials with stimuli that had a light source of 90 degrees were eliminated from the final analysis, resulting in 192 test trials. Participants' trials were aggregated and structured so that every combination of lighting direction (4), target location (4), and quadrant (4) was investigated. A 2x4x4x4 repeated measures analysis of variance (ANOVA) with the between-subject factor of native reading direction and within-subjects factors of scanning duration of quadrant, target location, and lighting direction was carried out to look for lighting conditions and target locations that facilitated shortest average durations for target identification and the quadrant in which the longest average durations occurred.

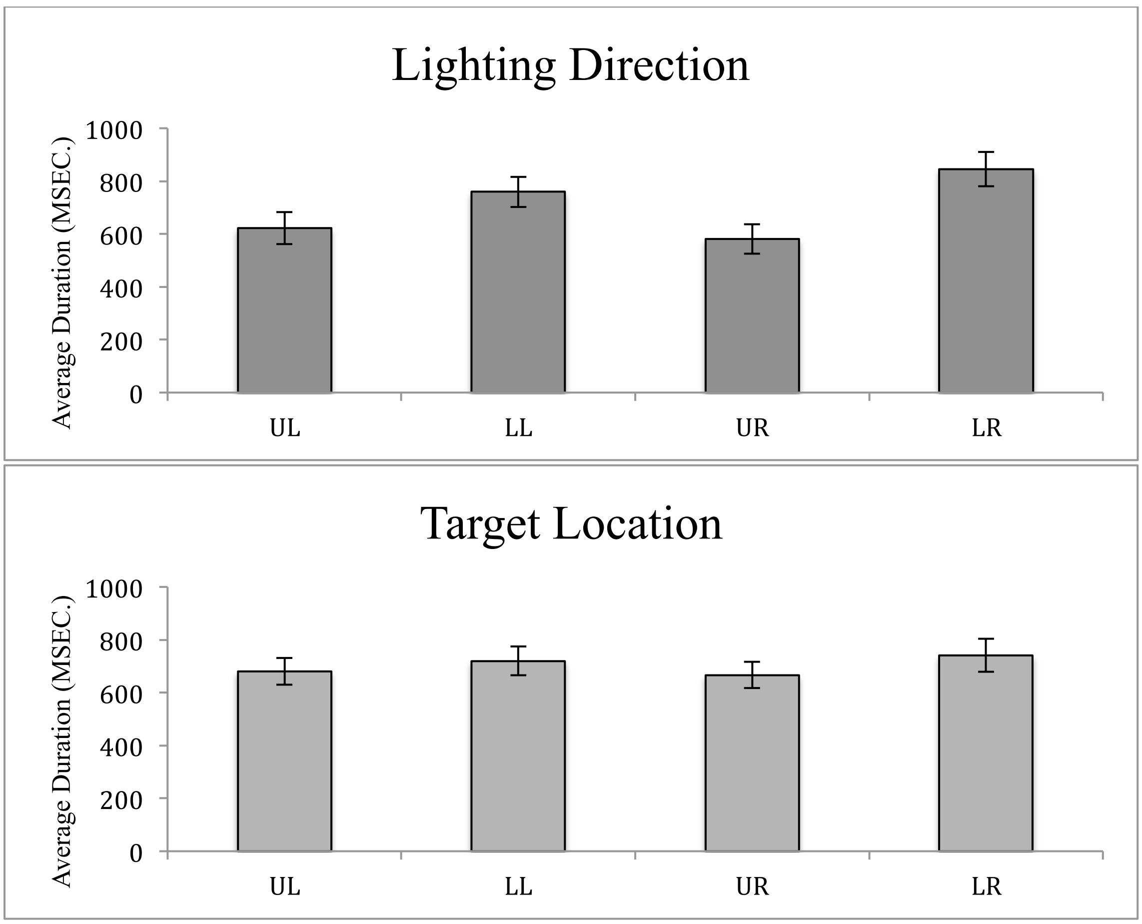
Results

The was a significant main effect of lighting direction, with top right lighting facilitating shortest durations for target identification, $F(3, 171) = 40.81$, $p < 0.001$, $\eta p^2 = 0.417$. A significant main effect of target location was also observed; the shortest durations were for targets located in the upper-right quadrant, $F(3, 171) = 7.54$, $p < 0.001$, $\eta p^2 = 0.117$. The longest durations occurred in the upper-left quadrant, seen in the significant main effect quadrant, $F(3, 171) = 34.48$, $p < 0.001$, $\eta p^2 = 0.377$. Left-to-right readers made significantly shorter durations overall, as a significant main effect of reading direction was observed, $F(1, 57) = 10.6$, $p = 0.002$, $\eta p^2 = 0.157$. Main effects are seen in figure 5.

Although the interaction between lighting direction and target location was significant, $F(9, 513) = 4.26$, $p < 0.001$, $\eta p^2 = 0.070$ (Figure 6), predictions of shorter durations for target identification for upper-left lighting/upper-left target location for left-to-right participants, and upper-right lighting/upper-right target location for right-to-left readers were not supported as the interaction between lighting direction, target location, and reading direction was not significant, $F(9, 513) = 1.02$, $p = 0.424$, $\eta p^2 = 0.018$. The three-way interaction between lighting direction, quadrant, and reading direction, $F(9, 513) = 2.764$, $p = 0.004$, $\eta p^2 = 0.046$, was significant (Figure 7), as well as the interaction between lighting direction and quadrant, $F(9, 513) = 8.10$, $p < 0.001$, $\eta p^2 = 0.124$. Predictions of longer durations in the upper-left quadrant under upper-left lighting for left-to-right readers and longer durations in the upper-right quadrant under upper-right lighting for right-to-left readers were not supported by post hoc paired-samples t-tests.

The interaction between target location, quadrant, and reading direction was significant, $F(9, 513) = 5.51$, $p < 0.001$, $\eta p^2 = 0.088$ (Figure 8), as well as the interaction between target location and quadrant, $F(9, 513) = 1212.57$, $p < 0.001$, $\eta p^2 = 0.96$. Post hoc paired-samples t-tests confirmed predictions about left-to-right readers, as durations in the upper-left quadrant were significantly longer when the target was located there. Right-to-left readers followed predictions by not exhibiting a leftward bias, even displaying a potential rightward bias as post hoc paired-samples t-tests found significantly longer durations of the upper-right quadrant when the target was located there than combination of lower-left target/lower-left quadrant, $t(30) = 2.536$, $p = 0.017$.

The interaction between reading direction group and quadrant was significant, $F(3, 171) = 3.76$, $p = 0.012$, $\eta p^2 = 0.062$ (Figure 9). Results from post hoc paired-sample t-tests for left-to-right readers supported predictions, as durations in the upper-left quadrant were significantly longer than all others. Right-to-left readers also followed predictions by failing to exhibit a leftward bias. Right-to-left readers' durations in the upper-right quadrant were significantly longer than both lower quadrants, but not the upper-left quadrant ($t(30) = 0.815$, $p = 0.422$). Both groups followed a similar pattern of increased durations in the upper quadrants.



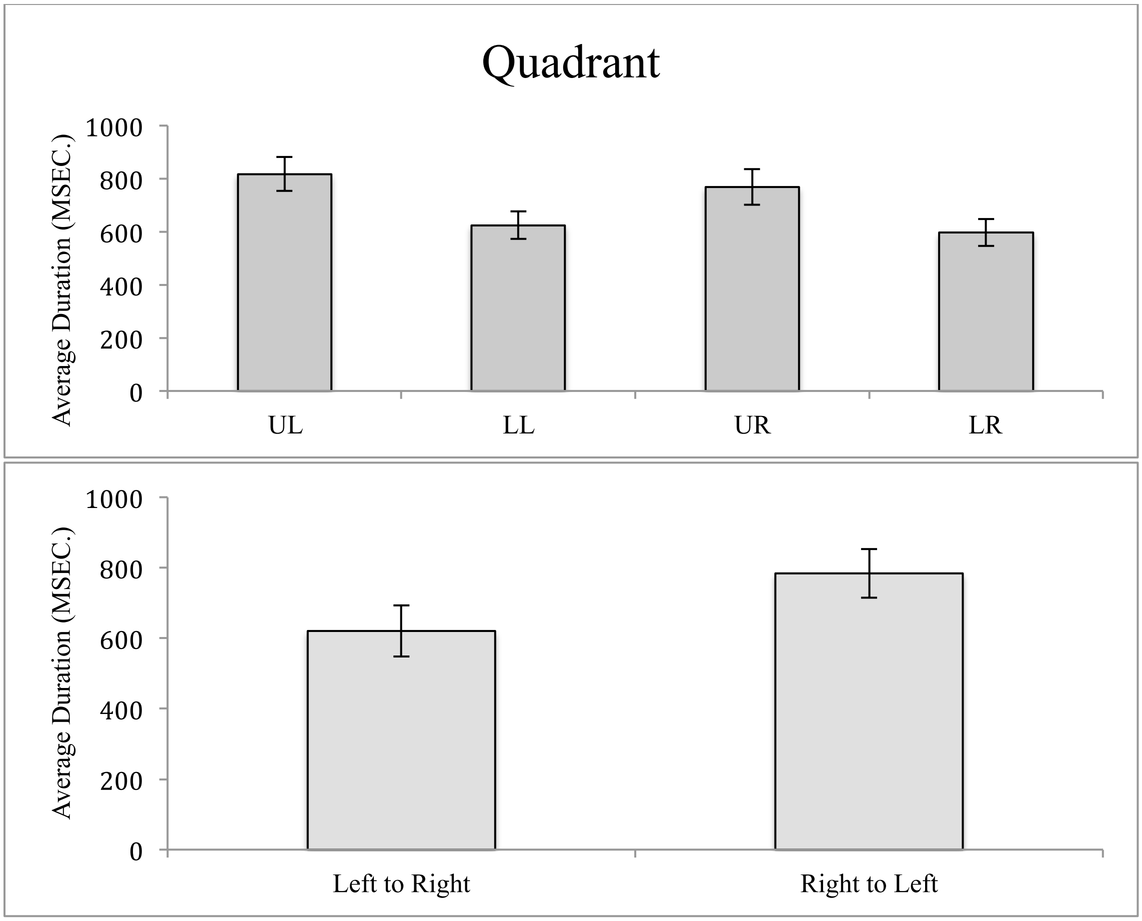


Figure 5. Main effects of lighting direction, target location, quadrant, and reading direction. Shorter durations for lighting direction, target location, and reading direction indicate faster target identifications. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

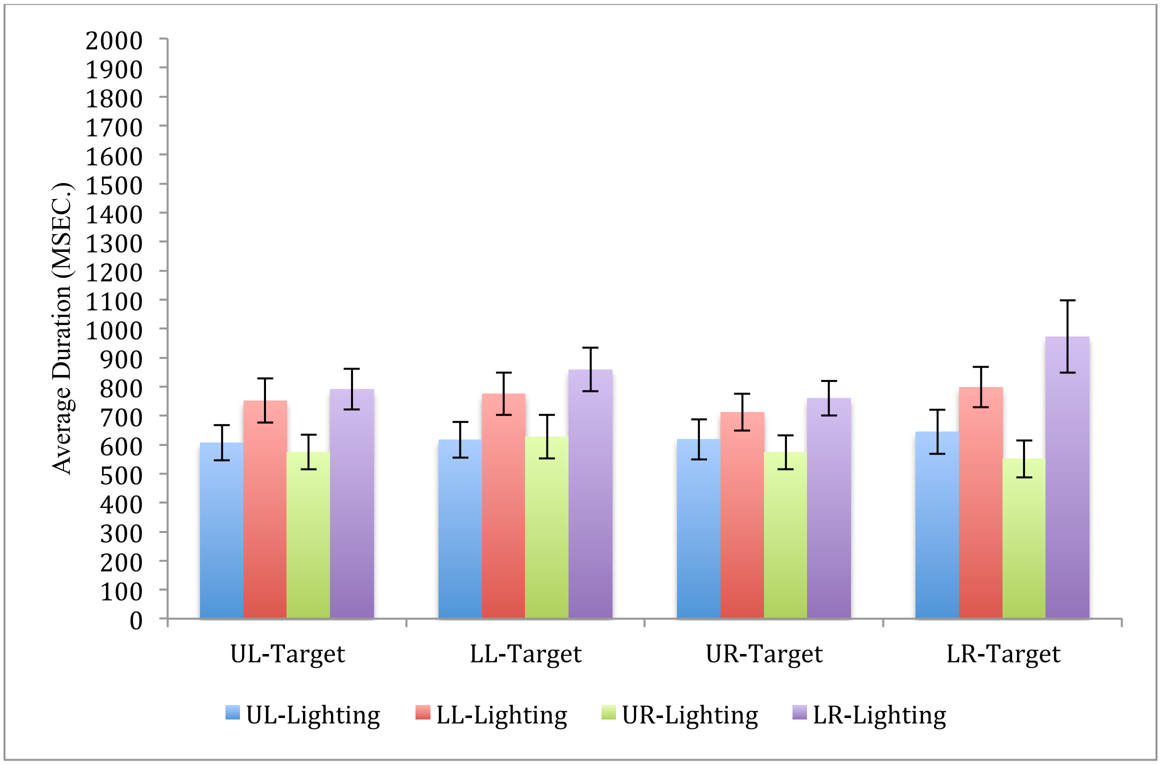


Figure 6. Interaction between lighting direction and target location. Shorter durations indicate faster target identifications. Error bars represent 95% confidence intervals.

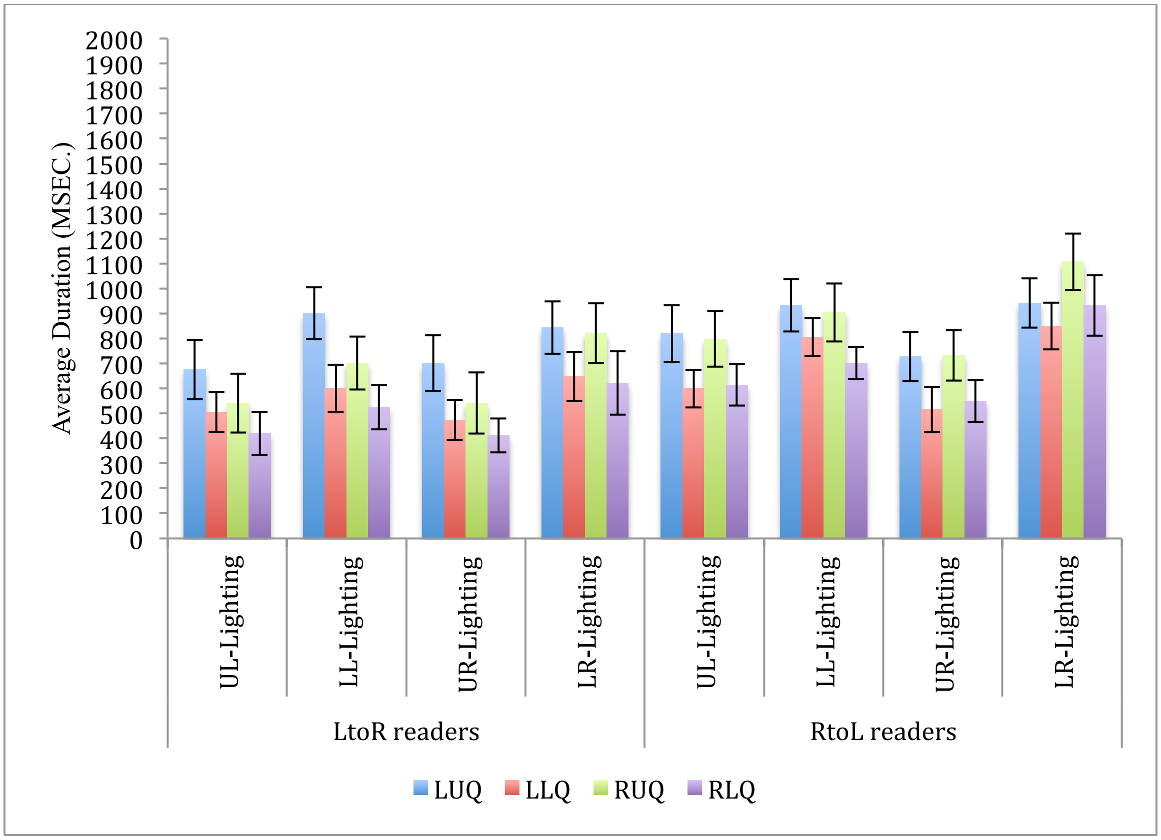


Figure 7. Interaction between lighting direction, quadrant, and reading direction. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

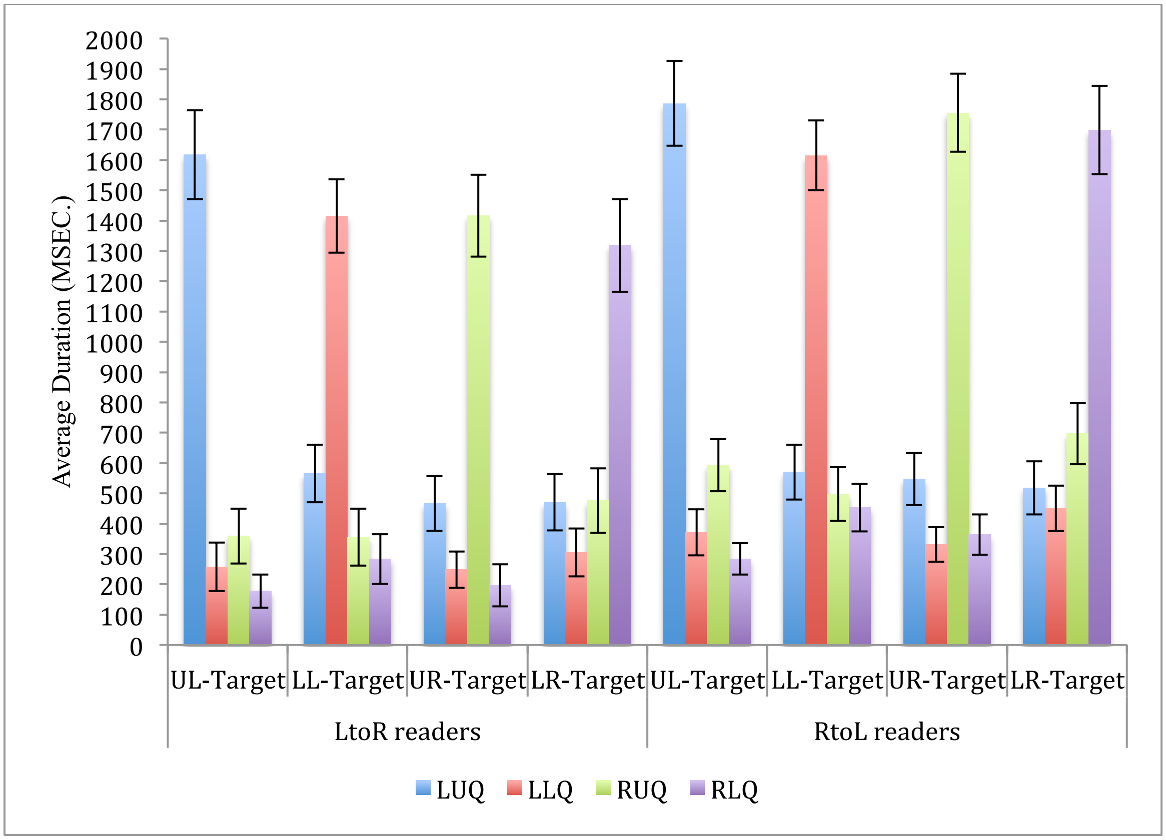


Figure 8. Interaction between target location, quadrant, and reading direction. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

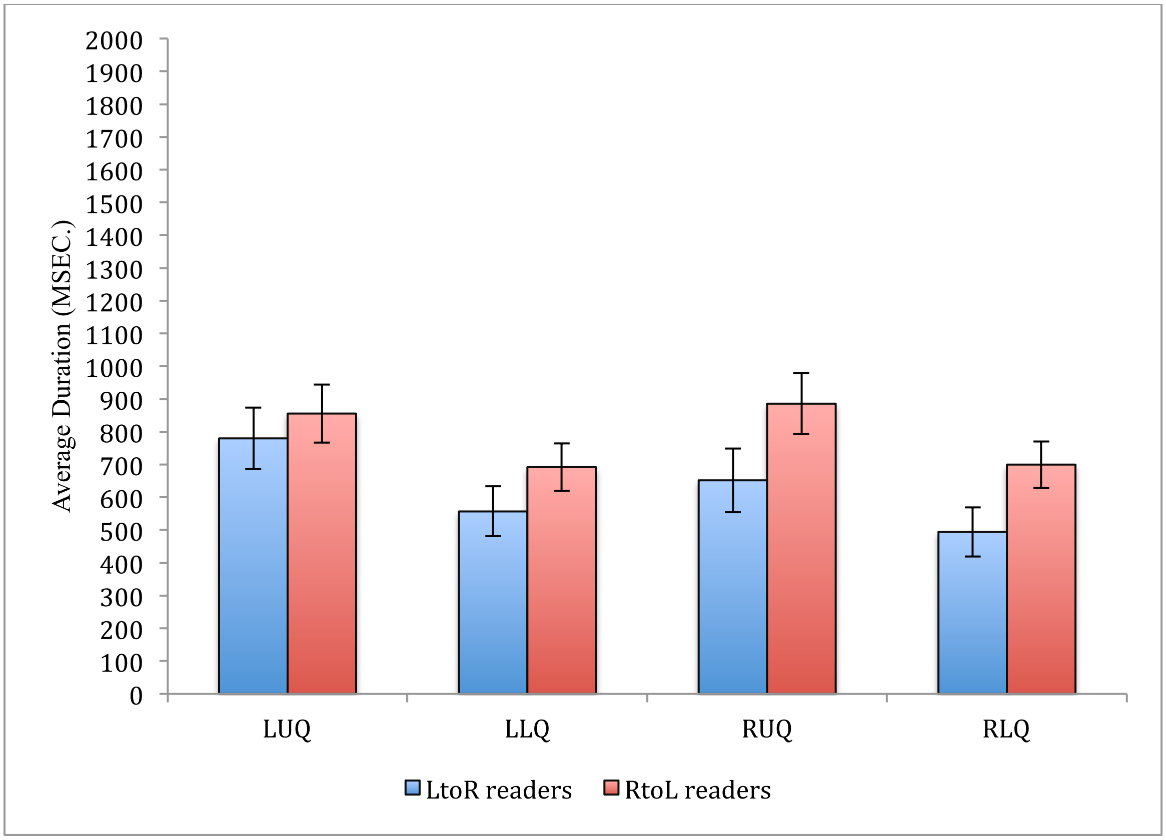


Figure 9. Interaction between reading direction and quadrant. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

Discussion

When comparing average duration times of left-to-right and right-to-left reading groups for lighting direction, the significant main effect of shortest duration times under rightward lighting appears to be driven by right-to-left readers. The lack of a significant difference between reading direction groups runs contrary to our predictions, but the non-significant target-finding advantage under right lighting for right-to-left readers is in line with out predictions. Further means comparisons revealed that light from above (both from the left and the right) facilitated shorter duration times for target identification than light from below. These results are consistent with previous findings of concave targets found quicker than convex ones (Kleffner & Ramachandran, 1992).

The main effect for shorter duration times for upper-right located targets was predicted for right-to-left readers, but was observed for both groups – indicating a reversal of what is predicted for left-to-right readers. However, pairwise comparisons found that upper-right and upper-left target locations did not significantly differ from each other. Pairwise comparisons indicate that significant differences exist between duration times for targets located in upper quadrants and duration times for targets located in lower quadrants, which is consistent with findings from previous target finding studies (Previc & Blume, 1993). The lack of a significant reading direction by target location interaction runs counter to our predictions.

Given that targets were found quickest when located in the upper-right, the main effect for the longest durations in the upper-left quadrant is a curious finding, as targets should be identified quickest in quadrants in which the most attention is paid. The finding of longest durations in the upper-left quadrant is, however, consistent with pseudoneglect theory, as it implies that the greatest allocation of attention is to the left side of space. Results from the significant interaction between reading direction group and quadrant support predictions for scanning distributions. Each group spent the longest durations visually exploring the side of space where, if images are explored in a similar fashion to text, scans are preferentially allocated. The longer durations of fixations in the upper quadrants observed in both groups is consistent with findings from past research. Previc and Blume (1993) suggest that target finding tasks occur in the FcE – the area of high visual acuity without a fixed depth (ranging from 10-20cm to 6m) in the central 30 degrees of the visual field – and that upper visual field advantages should be seen in tasks occurring here.

The significant interaction between target location, quadrant, and reading direction supports predictions and follows trends comparing left-to-right and right-to-left readers, as a leftward bias among left-to-right readers is observed, while right-to-left readers fail to exhibit the same bias, even tending to be biased towards the right. Additionally, a means analysis for both reading direction groups for the target location by quadrant interaction revealed a pattern of longer durations in the quadrant in which the target was located, indicating that participants completed the task as instructed and supporting our manipulation check. This eye-tracking information is important, as we did not build any other accuracy measures into the experiment.

The main effect of reading direction, with left-to-right readers making faster responses, was not predicted. The observed difference is intriguing, as the gap between groups is sizeable. A means comparison revealed that left-to-right readers averaged a decision time of 621 msec./trial and right-to-left readers averaged a decision time of 783 msec./trial, with 95% confidence intervals of 73 msec. and 69 msec., respectively.

The use of new equipment and software may have affected the outcome of this study. The RED-4 camera sampled at the same 60Hz rate as our previous RED-II camera but manual operation of the new RED-4 is significantly inhibited. Contrast and focusing adjustments, as well as calibration, are exclusively automatic, which cedes the control of the operator. This in and of itself is not necessarily negative, but does involve a learning curve as the operator moves to the new automated set up. Although the operator was confident running the equipment at the time of testing, puzzling results may, in part, be attributed to not being totally familiar with the finer details of the new system.

Additionally, the auto-accept option built into iViewX was used to indicate when a target was found. This seems like an excellent method for ascertaining highly accurate reaction time data, as it effectively eliminates any error occurring when the participant must press a key to indicate they have identified the target. During piloting of the study no serious problems with this method were encountered, however during testing issues did arise. Occasionally, when the target was located in the top row of the upper visual field the camera would not immediately recognize fixations on the target. This problem occurred for left-to-right and right-to-left readers and the experimenter noted affected trials, and these trials were excluded from the final analysis.

Questions remain about the relationship between native reading direction and performance on the shape from shading target finding task. Through the current study it is clear that performance differences between left-to-right and right-to-left readers exist. Future tasks may be designed to exclusively examine aspects from the research presented here, including potential lighting biases, potential spatial biases, and scanning distribution differences between left-to-right and right-to-left readers. Future studies may seek to explore the relationship of scanning distributions and target identification duration times, as the observed group main effect for scanning distributions from the current study was biased towards the upper-left, while the group main effect for target location was biased towards to the upper-right. This is puzzling, given the assumption that targets will be identified quicker in areas where more attention is allocated. The significant interaction between reading direction group and quadrant may require greater attention in future work, across other cognitive tasks known to reliably assess pseudoneglect, such as the greyscales task. Future research continuing to explore right-to-left readers' performance on cognitive tasks plays an important role in understanding the influence of cultural differences, as well as painting a more accurate picture of human neural organization.

CHAPTER 4

SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: RIGHT-TO-LEFT READERS

Data for chapter 4 was collected in the fall of 2012 at the University of Saskatchewan. Promising results from a sample of right-to-left readers in study 2 led to study 3 being carried out with a larger group of right-to-left readers. Similar procedures to studies 1 and 2 were carried out in study 3.

The first language an individual learns appears to influence spatial attention (Chokron & Imbert, 1993; Fagard & Dahmen, 2003; Morikawa & McBeath, 1992), and may be related to differences in the direction of eye movements (Abed, 1991; Nazir et al., 2004; Pollatsek et al., 1981). Previously it has been reported that neurologically normal people misperceive objects in the left hemifield as brighter, more numerous, and larger than those in the right hemifield, even if they are equivalent (Nicholls & Roberts, 2002; Nicholls et al., 1999). This phenomenon has for the most part been demonstrated with native left-to-right readers, with little attention paid to the influence reading direction may have.

This leftward attentional bias is commonly referred to as pseudoneglect, as it is a reversal of symptoms typically seen in clinical neglect patients, that is the neglect of leftward space (Bowers & Heilman, 1980). Pseudoneglect effects have not been replicated by all (Manning et al., 1990) but have been found robustly across a variety of studies. Leftward biases occur in lighting of artwork (Sun & Perona, 1998), in advertisements (Thomas et al., 2008), and in advertisement lighting preferences (Hutchison et al., 2011). Leftward biases are seen in species other than humans, as Regolin (2006) demonstrated with 9 day old chicks. Using an adapted line bisection task, birds were trained to peck at the centre bead. Side pecks were fewer than central pecks, but mistakes that were made were significantly leftward.

Further, in a pre-bisected line task McCourt (2001) found leftward errors in 91% of cases when participants indicate if a line has a leftward or rightward bisection. Mattingley et al. (1994) report similar spatial biases in neglect patients and controls in the greyscales task and when examining chimeric faces. With neutral/smiling chimeric faces and equiluminant rectangles neurologically normal individuals demonstrated a leftward bias when asked to determine the happier face and which rectangle is darker. Pseudoneglect effects do not appear to be limited to visual space. Using horizontal, vertical, and radial haptic line bisection Cattaneo et al. (2011) found neurologically normal blind folded sighted and blind participants to have a leftward bias in the horizontal condition. Additionally, sighted individuals were found to have downward and proximal biases of the vertical and radial conditions.

Although pseudoneglect effects have been demonstrated across a wide array of tasks, when native reading direction is included as a variable, certainty about the effect is questioned. In reading tasks, Nazir, et al. (2004) reported higher accuracy in identifying a target letter among a string of letters in the right visual field for native right-to-left reading Hebrew participants and the left visual field for native English readers. Additionally, saccades were found to be overall rightward for Hebrew readers and leftward for English readers. Pollatsek et al. (1981) also used a reading task with Israeli participants who read both Hebrew and English. Conditions for how much text was visible to the left and right varied, and it was found that performance was superior for reading Hebrew when more leftward text was revealed, as opposed to better performance when more rightward text was visible for English reading. Morikawa and McBeath (1992) proposed that native reading direction was responsible for bias in non-reading tasks as well. They found that by laterally shifting images of rows of diamonds, right-to-left readers did not exhibit the same leftward motion bias as left-to-right readers.

The exact influence that reading direction may have in cognitive tasks is not agreed upon. Nicholls and Roberts (2002) failed to find differences between English and Hebrew participants, while Barrett et al. (2000) also found no effect of reading direction with vertical left-to-right and vertical right-to-left Korean readers. Using the greyscales task and the line bisection task, Nicholls and Roberts provided evidence for attentional bias, calling into question the hypothesized influence of scanning biases in cognitive tasks. Barrett et al. also used a line bisection task, as well as drawing and spatial-syntactic tasks. A leftward bias was observed in both groups during line bisection and making drawings of a house, tree, and person on three separate pieces of paper. Participants in both groups showed no bias when drawing out the action of a sentence read out loud to them.

The leftward lighting bias is one phenomenon that has not received population variability scrutinizing that other tasks, like line bisection (Chokron & Imbert, 1993), grey scales (Nicholls & Roberts, 2002), reading (Pollatsek et al., 1981; Nazir et al., 2004) and aesthetic preference (Ishii et al., 2011) have received. In their study using convex-concave shaded spheres Sun and Perona (1998) describe the leftward lighting bias as the preferred lighting direction for the quickest identification of a target among a field of distractors. Research of the preference for left lighting over right or central lighting evolved out of studies examining light perception first described by Rittenhouse (1786), and subsequently by Ramachandran (1988) and Connor (2001). Rittenhouse, with bricks from the hearth, and Ramachandran and Connor with shaded spheres, discuss shape from shading. Illusions created when objects are lit from above, below, or laterally, with Ramachandran and Connor going on to postulate that the visual system is adapted for a single light source from above, in large part because of our solar system with one sun.

Continuing research with shaded objects, artwork, and advertisements has found that in fact leftward lighting is preferred (Sun & Perona, 1998; Mamassian & Goutcher, 2001; McManus et al., 2004; Elias & Robinson, 2005; Thomas et al., 2008; Hutchison et al., 2011; McDine et al., 2011).

Ever since Metzger's early observation of light from the left and right not being perceptually equivalent (Sun & Perona, 1998; McManus et al., 2004), little investigation has been carried out pertaining to the potential influence that scanning direction – influenced by reading direction – could have on this phenomenon. While completing a shape from shading target-finding task, we propose that conditions leading to average shorter durations for target identification and longer average durations in quadrants will differ from those previously observed in native left-to-right readers. Given the importance that native reading direction has on aesthetic light source perception (Smith & Elias, 2013), on spatial tasks, like line bisection (Chokron & Imbert, 1993), on dot filling and clock drawing tasks (Fagard & Dahmen, 2003), and on aesthetic judgments (Chokron & de Agostini, 2000; Ishii et al., 2011), we predict that right-to-left readers' average shorter duration times for identifying a target should occur under upper-right lighting conditions and upper-right located targets, or at minimum right-to-left readers will fail to exhibit a lateral bias. Further, right-to-left readers average durations are predicted to be longer in the central and right areas of visual space. Predictions follow from scanning bias theories that suggest participants should spend greater amounts of time examining the right side of images, also finding targets quicker when located there. Participants are predicted to examine stimuli in manner similar to reading, with more fixations allocated to the right side of space. Further, although not a formal prediction, average durations in each quadrant were thought to increase when the target was located there. This was a manipulation check to see if participants were indeed searching for the target, and indicating when it was found, as instructed.

Method

The Research Ethics Board at the University of Saskatchewan approved this study (Appendix I).

Participants

Thirty-two right-to-left reading individuals participated in the study. Data was not collected from one participant due to eye-tracking difficulty (glasses, dark eye make-up). Of the remaining 31 participants, 3 individuals were left-handed, 12 were female, and the average age was 30.2 (SD=5.9). Seventeen individuals had previously participated in research studies in our lab, but all were naïve to the goals of this task. All participants were bilingual, with their time spent in Canada varying from a few months to a few years. Participants received remuneration for their time. Table 4 provides a breakdown of participants' first languages.

Direction	Language	Number of participants
Right-to-Left	Arabic	3
	Persian (Dari)	1
	Persian (Farsi)	25
	Sindhi	1
	Urdu	1

Table 4. Participants' first languages including directionality of script.

Materials

A SensoMotoric Instruments (SMI) Remote Eye Tracking Device (RED 4) recorded participant eye movements at a frequency of 60 Hz. Eye data was passed through to iView X (2.7) operating on an SMI custom built PC with a 2.4 GHz Intel CPU and a 580 MHz Nvidia GeForce 9300M GS graphics card. Presentation of stimuli was done by Experiment Center (3.0) on a 1280x1024 resolution computer monitor.

Stimuli were the same shaded spheres used in experiments 1 and 2 (Appendix B), presented in a 4x4 array consisting of 15 spheres with the same lighting angle and one odd one out with an opposite lighting angle, e.g. 15 spheres at +45 degrees and one at -135 degrees. The stimuli were loosely based on other target finding experiments using illuminated spheres (Sun & Perona, 1998; McManus et al., 2004). In the array of 16 spheres the target occurred in each of the 14 lighting angles in each of the 16 positions, making for 224 test trails. Test trials were randomized and preceded by a calibration exercise and 4 practice trials, as in study 1 and 2. Handedness and footedness effects as potential co-variates were accounted for using the Waterloo Footedness Questionnaire–Revised developed by Elias et al. (1998) (Appendix C). Basic demographics, including first language, were collected in the questionnaire.

Procedure

Participants were welcomed and seated at a desk in a small windowless room with standard overhead fluorescent lighting. A brief explanation of the consent form (Appendix J) and the questionnaire (Elias et al., 1998) was given, followed by time to ask questions and complete the forms. After informed consent was obtained, participants positioned themselves comfortably in the chair while verbal and on-screen instructions were given to find the odd one out for each array of spheres and press space bar as soon as the target was identified. The experiment was programmed so that only after a central cross was fixated on for 500 msec. would the slide change to the next array of spheres. Before leaving, participants were given a debriefing form (Appendix K) explaining the experiment and the rationale behind it, and were thanked for their participation.

Coding and Analysis

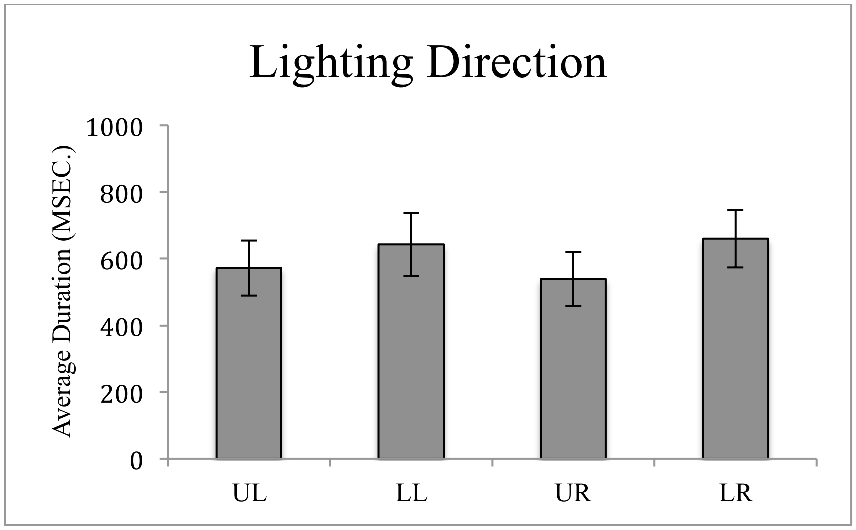
Eye movement data from iView was imported to iLab (Gitelman, 2002), where an analysis of the duration of time spent examining the upper-left quadrant, lower-left quadrant, upper-right quadrant, and lower-right quadrant was carried out. Lighting direction (of the array) and target location were coded for using the same quadrant divisions. Trials with stimuli that had a light source of 90 degrees were eliminated from the final analysis, resulting in 192 test trials. Participants' trials were aggregated and structured so that every combination of lighting direction (4), target location (4), and quadrant (4) was investigated. A 4x4x4 repeated measures analysis of variance (ANOVA) with within-subjects factors of lighting direction, target location, and quadrant was carried out to look for lighting conditions and target locations that facilitated shortest average durations for target identification and the quadrant in which the longest average durations occurred.

Results

The main effect of lighting direction, $F(3, 90) = 5.85$, $p = 0.001$, $\eta p^2 = 0.163$, was significant, with shortest average durations for target identification occurring under upper-right lighting (figure 10). Non-significant main effects for target location, $F(3, 90) = 1.43$, $p = 0.241$, $\eta p^2 = 0.045$, and of quadrant, $F(3, 90) = 0.132$, $p = 0.941$, $\eta p^2 = 0.004$, were also observed.

The three-way interaction between lighting direction, target location, and quadrant was significant, $F(27, 810) = 1.52$, $p = 0.044$, $\eta p^2 = 0.048$. To better understand this complex interaction, two-way interactions between lighting direction and target location, lighting direction and quadrant, and target location and quadrant were examined. Additionally, a means table from the three-way interaction is provided for further clarification (Table 5).

The interaction between lighting direction and target location, $F(9, 270) = 2.23$, $p = 0.020$, $\eta p^2 = 0.069$, was significant (Figure 11). The predicted shortest average durations for target identification by the combination of upper-right target location and upper-right lighting was not supported by post hoc paired t-tests. A significant interaction between lighting direction and quadrant was also observed, $F(9, 270) = 7.49$, $p < 0.001$, $\eta p^2 = 0.200$ (Figure 12). Follow up post hoc paired t-tests did not support the predicted increase in average durations in the upper-right quadrant under upper-right lighting. The interaction between target location and quadrant was significant, $F(9, 270) = 75.36$, $p < 0.001$, $\eta p^2 = 0.715$ (Figure 13). Post hoc paired t-tests supported predictions in that no leftward bias emerged, and that average durations increased in the quadrant where the target was located. Results show that when the target was in the upper-right quadrant, average durations in the upper-right quadrant were significantly more than other combinations, except for other congruent combinations of upper-left target/left upper quadrant ($t(30) = -0.825$, $p = 0.416$), lower-left target/lower-left quadrant ($t(30) = -0.728$, $p = 0.472$), and lower-right target/lower-right quadrant ($t(30) = -0.635$, $p = 0.530$).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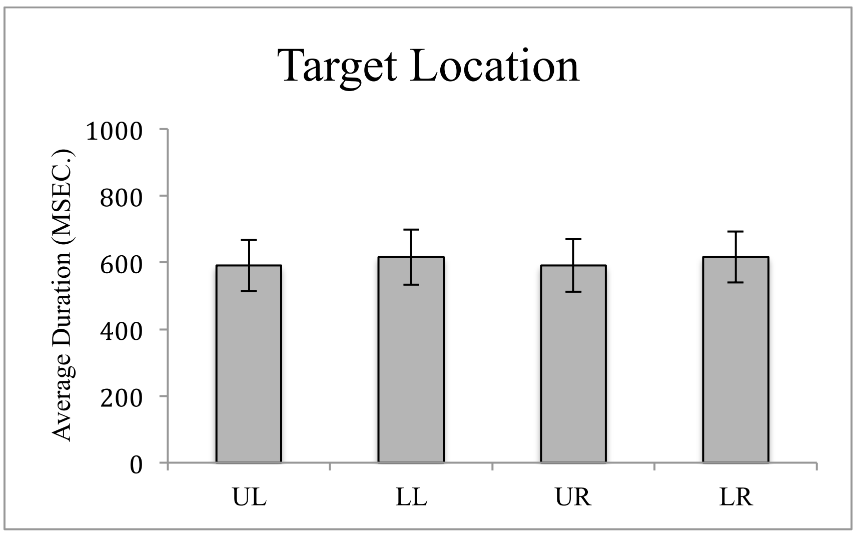
Target Location
Average Duration (MSEC.)
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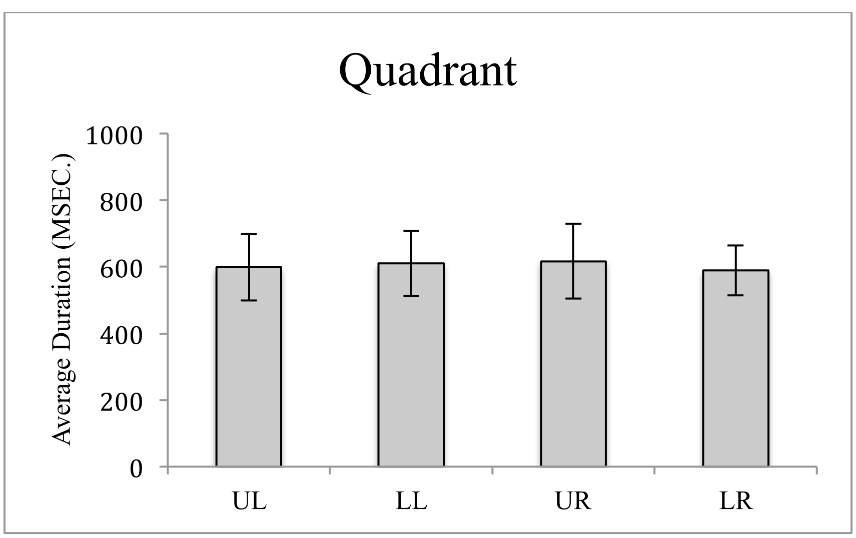
Quadrant
Average Duration (MSEC.)
1000
800
600
400
200
0
UL
LL
UR
LR

Figure 10. Main effects of lighting direction, target location, and quadrant. Shorter durations for lighting direction and target location indicate faster target identifications. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

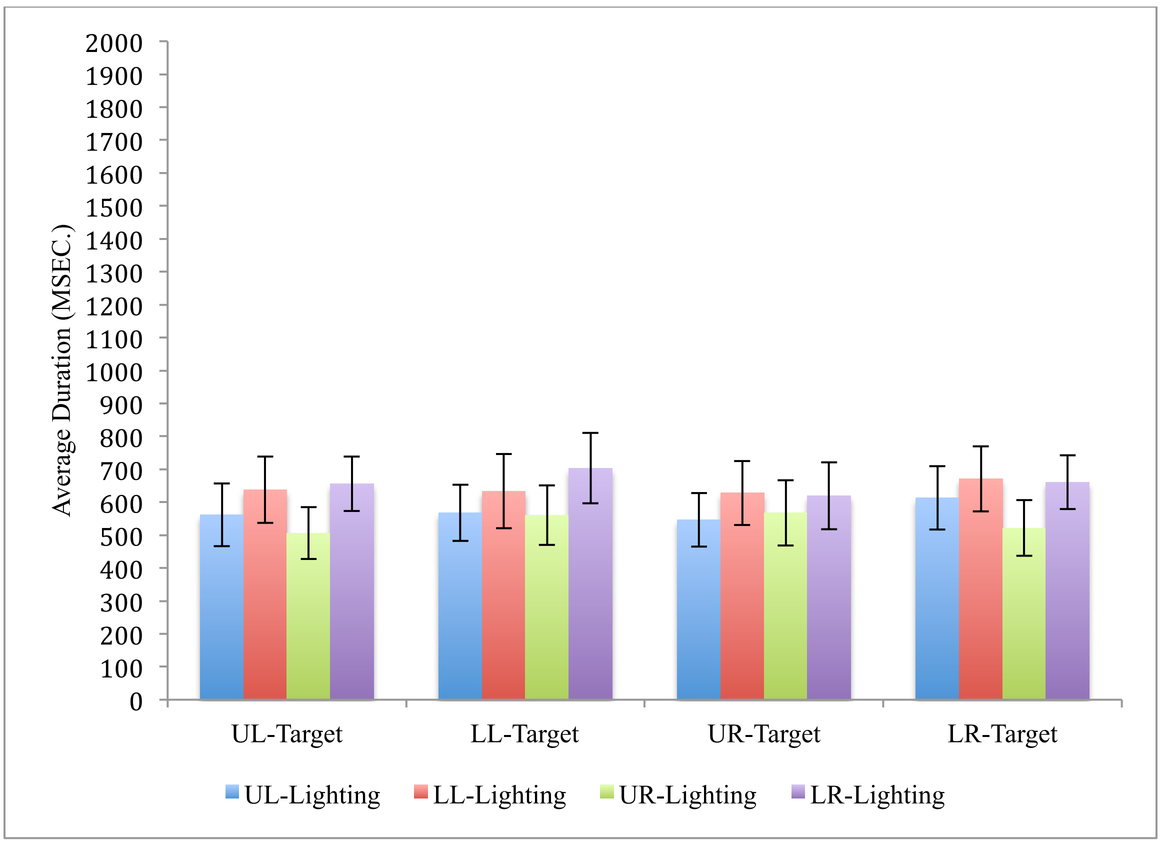

Figure 11. Interaction between lighting direction and target location. Shorter durations indicate faster target identifications. Error bars represent 95% confidence intervals.

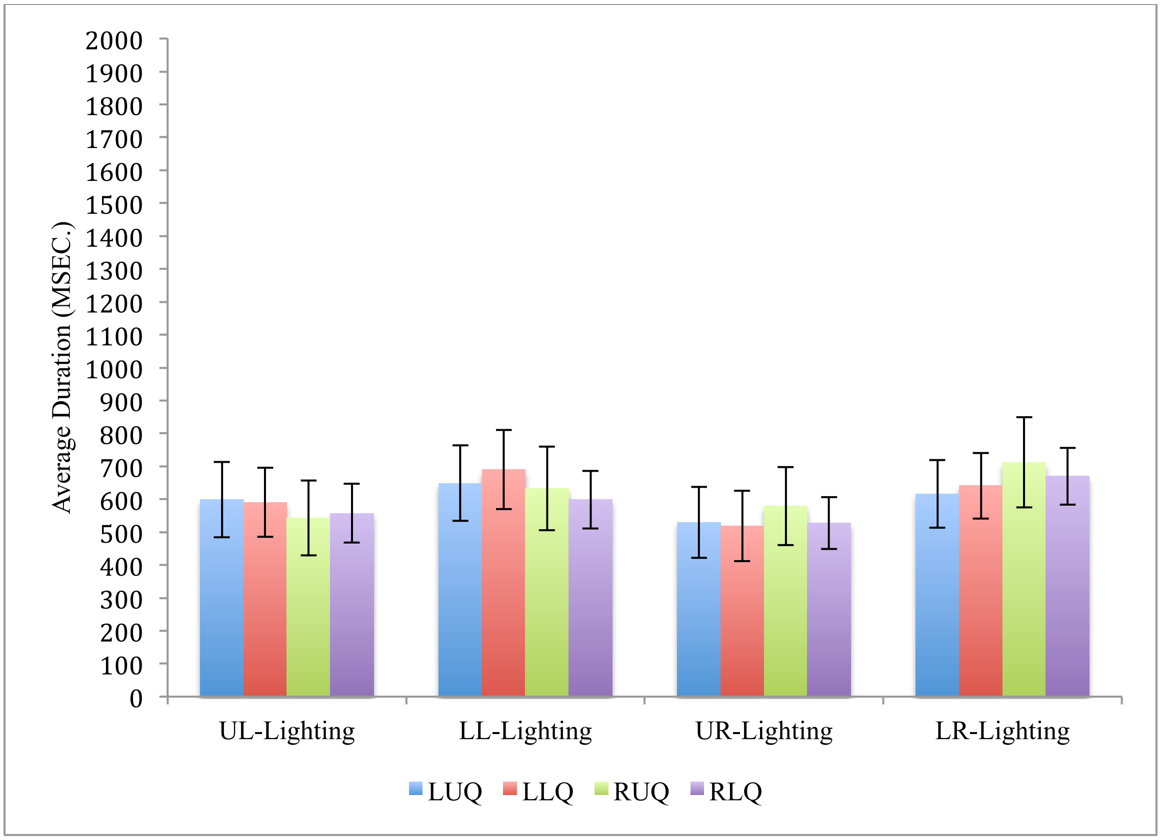

Figure 12. Interaction between lighting direction and quadrant. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

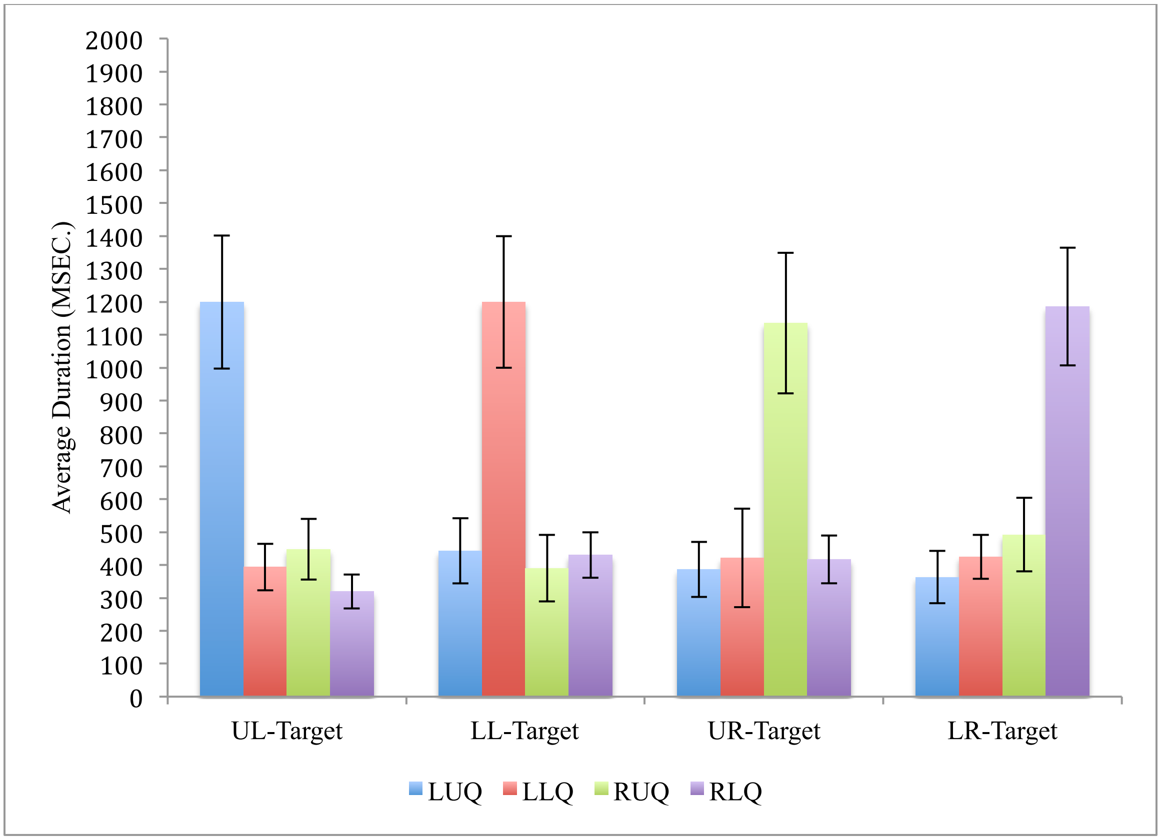

Figure 13. Interaction between target location and quadrant. Longer durations for quadrant indicate prolonged examination of quadrant. Error bars represent 95% confidence intervals.

		UL-Target	LL-Target	UR-Target	LR-Target
UL-Lighting	LUQ	1201.608	424.965	402.01	366.038
	LLQ	359.489	1189.4	377.658	435.754
	RUQ	381.404	297.836	1072.641	417.877
	RLQ	304.506	359.2	333.336	1232.229
LL-Lighting	LUQ	1268.884	465.109	437.832	422.854
	LLQ	468.673	1257.531	504.477	529.241
	RUQ	478.582	382.515	1147.825	523.893
	RLQ	334.853	428.94	422.7	1208.397
UR-Lighting	LUQ	1086.534	380.235	364.856	286.795
	LLQ	319.717	1077.996	386.358	289.921
	RUQ	356.76	406.079	1122.694	431.013
	RLQ	259.719	375.282	396.723	1077.503
LR-Lighting	LUQ	1240.451	503.989	342.926	376.949
	LLQ	427.565	1273.733	418.382	445.444
	RUQ	575.379	475.621	1200.473	596.19
	RLQ	380.203	557.799	517.139	1225.904

Table 5. Means table from the interaction between lighting direction, target location, and quadrant.

Discussion

The hypothesis that reading direction modulates lighting bias, specifically that right-to-left readers average duration times for target identification are shorter under upper-right lighting, is supported by the data. Findings from the current study differ from results of past studies finding opposite upper-left light facilitating shortest durations for finding a target, even though similar stimuli and methodology have been used (McManus et al., 2004; Sun & Perona, 1998).

Although predicted rightward biases for shorter average durations for target identification based on target location and increased average durations for the upper-right quadrant did not reach statistical significance, examining the means revealed near identical duration times for targets located in the upper-right and upper-left quadrants. As well, increased durations for the upper-right quadrant were found. Behaviours of right-to-left readers observed in the current study follow trends of weaker leftward, or a lack of lateral, biases observed in studies employing different cognitive tasks while assessing differences of native reading direction (Abed, 1991; Morikawa & McBeath, 1992).

As was observed in study 1 and 2, a significant interaction occurred between the location of the target and quadrant, with the greatest average durations being in the quadrant that contained the target, in line with informal predictions. This indicates that participants completed the task as instructed, pressing the space bar and advancing to the next trial only after finding the target.

Hypotheses are supported by the data, and are consistent with past findings of upper visual field advantages in target finding studies (Previc & Blume 1993) and studies finding lighting from above to be preferred (Kleffner & Ramachandran, 1992). The data is also out of line with past findings of a leftward lighting bias (Sun & Perona, 1998; McManus et al., 2004). Previc and Blume suggest that target finding tasks occur in the FcE – the area of high visual acuity without a fixed depth (ranging from 10-20cm to 6m) in the central 30 degrees of the visual field – and that upper visual field advantages should be seen in tasks occurring here. Results from a means analysis of target identification according to location support these past findings. Results of light from above (left and right) eliciting significantly quicker target identification reaction times support Kleffner and Ramachandran's conclusion that concave targets are easier to identify against backgrounds of convex distractors.

The finding of upper-right lighting facilitating the shortest reaction times for finding a target is at odds with previous studies examining lateral differences in lighting (Sun & Perona, 1998; Mamassian & Goutcher, 2001; McManus et al., 2004; Elias & Robinson, 2005), and opens the door for future research to further explore illumination differences between groups with native reading directions other than left-to-right. In most cases the observed leftward lighting bias has, for the most part, been unsatisfactorily explained. Previous studies have failed to account for native reading direction as a potential factor influencing results, as these studies have exclusively been comprised of left-to-right reading participants. Our results of right-to-left readers showing a reversal in light source preference for target identification suggest that conclusions drawn about a universal preference for leftward lighting may actually be specific to left-to-right readers. Our results support previous findings from studies examining light source perception, where right-to-left readers exhibit different behaviours than left-to-right readers in image preference (Smith & Elias, 2013). More broadly, findings from the current study support research proposing that native reading direction influences scanning behaviour and that, in turn, scanning behaviour influences perception of space (Abed, 1991; Chokron & Imbert, 1993; Fagard & Dahmen, 2003).

Future studies exploring potential differences arising from native reading directions other than left-to-right may choose to assess visual search using a more traditional target-finding paradigm, utilizing stimuli that do not require the perception of shape from shading. Further eye movement data can be collected from experiments evaluating real world tasks, such as operating an automobile. Better understanding how native languages influence where individuals are paying attention to while driving provides valuable information when designing infrastructure.

CHAPTER 5

GENERAL DISCUSSION

The perception of three-dimensions when viewing 2D information from an object is a complex visual process that is accomplished by the brain using information gained by making assumptions about the object and the environment (Langer & Bulthoff, 2001; Ramachandran, 1988). Assumptions need to be made despite the unparalleled computing power of the human brain, as the vast amount of incoming visual information cannot be efficiently processed in its entirety. This learning process involves carefully calculated assumptions that allow humans to believe they have full colour vision and a complete picture of their visual field. The areas of black and white only vision and spaces in the visual field that fall on the blind spot are carefully compensated for based on current and previous experience. These assumptions are consistently demonstrated in neurologically normal individuals, across geographical location and cultures. Other assumptions of the visual system may be learned in different ways, depending on external factors. In their well-designed study with left-to-right and right-to-left reading participants (ranging from pre-reading age, to learning to read, to accomplished reader), Fagard and Dahmen (2003) demonstrated the powerful effects learning to read and write in one language instead of another.

Our visual system has been optimized for perceiving light from above because of our existence on a planet with a single overhead light source, the sun (Connor, 2001; Ramachandran, 1988). This assumption has been tested using stimuli devoid of visual cues usually present, like stereopsis, so shading becomes the only visual cue available to make a decision about the stimuli. Tasks of this nature are commonly called *perception of shape from shading*; shaded circles are often used as they create concave and convex spheres (Ramachandran, 1988). When shaded on a horizontal gradient, stimuli appear as 3D convex or concave bubbles, but when shaded on a vertical gradient the 3D effect is lost. Evidence from animal and human studies point to the visual processes involved in the perception of three dimensions to occur relatively fast in visual perception. Presenting ambiguously lit stimuli to monkeys, Hanazawa and Komatsu (2001) used single cell recording to track firing patterns of 3D perception. Hanazawa and Komatsu suggest that shape from shading and 3D perception does not involve complex cells, rather, it most likely occurs in area V4. In humans, Kleffner and Ramachandran (1992) suggest that the perception of shape from shading occurs early in visual processing, given the dependence for the effect on retinal (instead of gravitational) cues. Neuroimaging data from Humphrey, Goodale, Bowen, Gati, Vilis, Rutt, and Menon (1997) and visual evoked potentials recorded by Hou, Pettet, Vildavski, and Norcia (2006) support this claim, as during shape from shading tasks participants' performance suggest that 3D feature extraction from ambiguously lit stimuli occurs in areas V1, V2, & V4.

When perceiving shape through shading, light from above creates convexity, and light from below creates concavity. It follows from the preference for light from above that convexity is preferred to concavity (Gerardin et al., 2007; Langer & Bulthoff, 2001). Although light from above and convexity appear to be default assumptions made by the visual system, Adams et al. (2004) and Champion and Adams (2007) have found that through haptic training these assumptions can be changed.

Light from above-left appears to be an additional default assumption that the visual system makes (Elias & Robinson, 2005; Mamassian & Goutcher, 2001; Mamassian et al., 2003; Sun & Perona, 1998). Researchers have had more difficulty explaining the above-left lighting prior than light from above and convex priors. The human visual system learning that light usually originates from above, from the sun, is the widely held explanation for the light from above prior, and the consequent prior for convexity (Ramachandran 1988; Langer & Bulthoff, 2001). Potential explanations for the leftward lighting bias range from handedness (Sun & Perona, 1998) or head tilt (McManus et al., 2003) of the observer, neural organization of V1 and areas first processing visual information (Mamassian et al., 2003), and various cerebral lateralization differences related to other leftward perceptual biases (Mamassian & Goutcher, 2001; McDine et al., 2011; Thomas et al., 2008). Although the mechanism in action for the observed leftward lighting bias is unknown, when participants observe psychophysical stimuli (Elias & Robinson, 2005; Gerardin et al., 2007; Mamassian & Goutcher, 2001; Mamassian et al., 2003; Sun & Perona, 1998), or aesthetic stimuli such as advertisements (Hutchison et al., 2011), leftward lighting is robustly preferred. Further, when advertisements (Thomas et al., 2008) or artwork (Sun & Perona, 1998) are produced, or when illuminating abstract artwork (McDine et al., 2011), a leftward lighting bias emerges.

Searching for a clear explanation for observed leftward biases in aesthetics and perception and attention tasks, has led some to explore lateral differences between groups of individuals who read and write in different, often opposite, directions. Results from studies exploring potential cultural differences have been mixed, and until a recent study by Smith and Elias (2013), never applied to lighting biases. Although Jewell and McCourt (2000) concluded that scanning direction is one of the greatest modulating factors of pseudoneglect, Nicholls and Roberts (2002) report leftward biases among left-to-right reading English and right-to-left reading Hebrew participants on greyscale and line bisection tasks. Chokron and Imbert (1993) also assessed left-to-right (French) reading and right-to-left (Hebrew) reading participants' performance on a line bisection task and found errors to mirror the direction in which the participants' native reading direction scans begin. Barrett et al. (2002) found both vertical left-to-right and vertical right-to-left Korean readers to demonstrate a leftward bias in line bisection and when asked to make drawings of a house, tree, and person on three separate pieces of paper and no bias when drawing out the action of a sentence read aloud to them. Studies carried out with children examining line bisection, dot filling, and clock drawing (Fagard & Dahmen, 2003), with adults for inhibition of return (Spalek and Hammad, 2005), with adults on reading tasks (Pollatsek et al., 1981; Nazir et al., 2004), with adults in aesthetics (Chokron & De Agostini, 2000), and in portrait composition (González, 2012), have all found native reading direction to reverse lateral biases.

Biases regulated by native reading direction have been identified in research areas traditionally not considered when exploring lateral biases. From a social psychology perspective, Maass et al. (2009) assessed the influence that native reading direction may have on the spatial agency bias. Maass et al. found that left-to-right reading (Italian) participants place the more agentic groups of men and young people to the left, while right-to-left reading (Arabic) participants display an opposite bias by placing more agentic groups to the right. Both Ishii et al. (2011) and Chokron and De Agostini (2000) report aesthetic preferences for directionality of static and motion images matching their native reading direction (left-to-right directionality for left-to-right readers, and vice versa for right-to-left readers). González (2012) compared composition of photographs from a right-to-left (Iranian) reading culture to a left-to-right (Spanish) reading one. For 3 of the 5 measures of composition examined, he reports directional biases for each group that mirrors native reading direction. Further, Spanish photographs show the sitter's left cheek significantly more than in Iranian photos.

Smith and Elias (2013) carried out a study comparing left-to-right reading and right-to-left reading participants scanning distributions and aesthetic preferences on an image comparison task. Images had a clear light source and were presented concurrently with their mirror image above or below. Left-to-right readers examined the left side of images more and preferred left lit images. Right-to-left readers did not exhibit the same leftward biases; rather they displayed non-significant rightward scanning distributions and rightward lit image preferences. This is the first study to examine the influence of native reading direction on light source perception and aesthetics.

The divergence observed between groups with different reading directions appears to at least in part be attributable to scanning habits, which are influenced by native reading direction. Abed (1991) proposed that non-directional stimuli, a line drawing or target finding array for example, are visually explored in a manner similar to reading. In their study of left-to-right readers only, Thomas et al. (2008) suggest that advertisements are scanned roughly following the shape of a Z, starting at the top left corner, scanning across to the top right corner, scanning diagonally down to the bottom left corner, and finishing in the bottom right corner.

Although it is not known what the extent of the influence of an individual's native language has in aesthetic preference or in cognitive task performance, many of the documented leftward biases may exist in part because the population from which they were derived reads from left-to-right. Few researchers account for differences between groups with different reading directions, yet generalize their results to all humankind. This leads to models of brain organization and cognition, based on a subpopulation that lacks cultural variability. Results from studies that have examined the potential effects that reading direction may have on task performance have been mixed, particularly for classical measure of pseudoneglect like line bisection and greyscales (Chokron & Imbert, 1993; Nicholls & Roberts, 2002). Tasks examining directionality and aesthetics, however, have yielded results more indicative of native reading direction's influence on visuo-spatial tasks. Our aim is not to undermine existing models built on differences in cerebral lateralization, proposed to be common to all humans. Rather, we highlight the assumption that findings from past research examining lateral biases are generalizable, even though data supporting them are largely from college aged Western individuals. Results from the current studies emphasize this last point, as we present evidence that native reading direction modulates lighting biases.

Similarities and difference between left-to-right readers and right-to-left readers have been identified across all 3 studies. This suggests that there is a certain amount of neurological organization associated with perceptual biases that spans across cultures, as well as aspects of cultural individuality that influence perception. Commonalities in neurological organization involved with perception most likely lie in areas identified as largely responsible for spatial reasoning – typically in the right hemisphere, predominately the parietal, fronto-parietal, and occipito-temporo-parietal regions. The light source perception aspect of the task in the current studies appears to be influenced by reading and writing aspects of a culture. These results highlight the importance of ascertaining a culturally diverse sample when investigating perceptual asymmetries, or other phenomenon in the psychological or physical realms.

Shortest average durations for target identification, regardless of reading direction group or target location, occurred when the light source originated from an angle less than 90 degrees. This gave the illusion that the array was illuminated from above, or that a concave target was among a field of convex distractors. This finding is consistent with Kleffner and Ramachandran's (1992) seminal findings of concave stimuli being identified easier. Further, results from studies 1 and 3, which had larger samples, indicate that left-to-right readers exhibited shortest average durations for target identification when the array was lit from above-left, while right-to-left readers demonstrated shorter average durations for target identification under above-right illumination.

Both reading direction groups demonstrated shorter average durations for identifying targets quicker when located in the upper visual field (upper-left and upper-right quadrants). When examined alone, right-to-left readers did not exhibit any significant lateral preferences for target location, but when grouped with left-to-right readers in study 2 a rightward preference emerges. Contrary to this, in study 1 left-to-right readers identified targets quicker when they were located in the upper-left quadrant. Heterogeneous as they are, results for target identification from the current studies are somewhat at odds with past research examining the spatial relations of finding a target. Upper and right visual fields have been identified as areas of visual space that facilitate quicker target identification (Previc, 1998; Previc & Blume, 1993), and an association between lower and left visual fields has also been observed (Christman & Niebauer, 1997). These are flexible associations though, as the presentation time of stimuli has been shown to change upper/lower & right/left visual field pairings (Thomas & Elias, 2011) and visual field advantages (Rezec and Dobkins, 2004). Left-to-right readers' results for target identification based on location from study 1, and the lack of a leftward bias for shorter target identification among right-to-left readers from study 3, provide support the hypotheses. However, the results from study 2 that conflict with studies 1 & 3 make it clear that this aspect of target location from our study requires further research.

From the current studies, comparable findings between left-to-right and right-to-left readers arise when overall amount of inspection time is considered. Results from the current studies show that there are differences between groups, as left-to-right readers display longer durations in the upper-left area of space and right-to-left readers display longer durations in the upper-right area of visual space. The common ground between groups is that the upper visual field (both upper-left and upper-right quadrants) is explored more than the lower visual field (lower-left and lower-right quadrants). This finding is consistent with past research from Previc and Blume (1993).

Lastly, when examining average duration of time/quadrant and target location, a strong interaction effect occurs across all 3 studies. Although we made predictions concerning lateral biases specific to each reading direction group, upon further inspection it is clear that this effect is driven by the quadrant containing the target also receiving the greatest average duration time. This is an important manipulation check for our target finding task, ensuring that participants completed the task as instructed. Past studies using a target a finding paradigm, such as Sun and Perona (1998), often only have a target present for half of the trials to ensure that participants are completing the task correctly.

Taken alone, the leftward biases for shortest target identification for array illumination, target location, and the greatest durations for the upper-left quadrant exhibited by left-to-right readers from study 1 support past research examining lighting biases and past findings in pseudoneglect literature. Considering right-to-left readers' rightward biases for illumination and observed lack of bias for target location and greatest durations in a quadrant, leftward lighting bias theory and aspects of pseudoneglect theory are challenged. Rather, the trend toward directional influences of reading and writing, consistent with Chokron and De Agostini (2000) examining aesthetics and Fagard and Dahmen (2003) investigating basic cognitive tasks, is supported. These results suggest that reading direction may influence perceptual tasks more so than cerebral dominance, as was once a common explanation (Levy, 1975; Beaumont, 1985).

Data presented here does not undermine these established neurological correlates to behavioural biases. Rather, this data suggests that there is more to the story when it comes to perceptual asymmetries of light sources, and perhaps even pseudoneglect, than was once thought. Based on results from the current studies, we suggest the cultural influence of reading and writing alters perception. It is difficult to speculate to what degree of real world perception is affected, but we can say with confidence that light source perception is altered depending on which direction one's native language is read and written.

More studies, covering a broader range of perceptual tasks, must be carried out before any suggestion of a mechanism can be reasonably made. At this point, based on a limited amount of data concerned with light source perception and native reading direction, that is, results from the current studies and Smith and Elias (2013), only incomplete inferences can be made. We predict that the intense training one undergoes to learn to read and write either work with or against left visual field advantages driven by right parietal dominance for spatial processing. In the case of learning English, or another left-to-right language, an individual is trained to focus attention first to the left and then make their way to the right, and then back to the left, enabling a leftward bias already in place by neurological organization. For an individual who is learning to read and write a language such as Farsi, which is read and written right-to-left, attention is directed in an opposite manner: scans begin on the right and work left, and then return to the right. Attention is preferentially being directed to the right visual field, one that the right parietal lobe normally receives less information from than the left visual field. This may have a neutralizing effect on leftward biases – either by increasing the spatial ability of the left parietal lobe, or by the lack of extra practice for the right parietal lobe.

The current study is not without limitations. One limitation is in the groups that comprise our samples. As most left-to-right reading individuals were English monolinguals, ideally they would be matched to a group of monolingual right-to-left readers, but our sample consisted of bilingual individuals. Given our geographical location in the Canadian plains, obtaining this sample was not feasible. Addressing this issue is an opportunity for future research. Additionally, highly accurate scanning distributions may not have been recorded due to the way stimuli were presented in the current study. Presentation was optimized for an easy direct image comparison; future experiments that present a single image may yield more precise scanning distributions and avoid this limitation.

The use of new equipment and software may have affected the outcome of this study. The RED-4 camera sampled at the same 60Hz rate as our previous RED-II camera but manual operation of the new RED-4 is significantly inhibited. Contrast and focusing adjustments, as well as calibration, are exclusively automatic, which cedes the control of the operator. This in and of itself is not necessarily problematic, but does involve a learning curve as the operator moves from manual to automatic operation. Although the operator was competent running the equipment at the time of testing, puzzling results may, in part, be attributed to not being totally familiar with the finer details of the new system. The RED-II was used in experiment 1, while the RED-4 was used in experiments 2 and 3.

Additionally, the auto-accept option built into iViewX was used to indicate when a target was found in experiment 2. This seems like an excellent method for ascertaining highly accurate reaction time data, as it should eliminate any error that may occur when the participant must press a key to indicate they have identified the target. During piloting of the study no serious problems with this method were encountered, however during testing some issues did arise.

Occasionally, when the target was located in the top row of the upper visual field, the camera would not immediately recognize fixations on the target. This issue occurred for both left-to-right and right-to-left readers; affected trials were noted at the time of testing and were excluded from analysis. Other inconsistencies between studies included the use of a chin rest, to reduce participant head movement, in studies 1 and 3 and no chin rest in study 2; as well as space bar presses to indicate target identification in studies 1 and 3 and an auto-accept method based on eye tracking used in study 2.

The relationship between pseudoneglect and lighting biases is still not clear. Continuing work in light source perception, aesthetics, pseudoneglect, and cross-cultural research should strive toward better understanding this relationship, or even if such a relationship does exist. It is tempting to see the shared leftward bias in both pseudoneglect and leftward lighting bias phenomenon and group them together as different expressions of the same phenomenon. However, this may not be the case. The leftward lighting bias appears to be modulated by native reading direction (Smith & Elias, 2013; current experiments), more similar to aesthetic and perceptual biases affected by first language learned (Chokron & De Agostini, 2000), whereas reports of native reading direction affecting, or reversing, leftward biases in pseudoneglect are inconsistent (Fagard & Dahmen, 2003; Nicholls & Roberts, 2002). The separation between pseudoneglect and other perceptual biases is perhaps most clearly illustrated in studies by Chokron and De Agostini (2000) and Ishii et al. (2011) which compare results from groups with different reading directions on measures of aesthetics and a task (as well as a line bisection task used by Ishii et al.) more akin to measures traditionally used to assess pseudoneglect. Here we see in both studies that while aesthetic preferences are modulated by native reading direction, performance on a more classic pseudoneglect task is not.

As our current set of experiments has produced heterogeneous findings for the question of *"Where in space are targets located most quickly"*, it is obvious that further research investigating target finding must be carried out with shape from shading stimuli. Lateral biases reported in other studies are mixed as well. A leftward bias is consistently reported in studies evaluating pseudoneglect, often using measures such as line bisection and image comparison, but in a meta-analysis of line bisection by Jewell and McCourt (2000) contrary evidence of an opposite rightward bias or lack of bias is presented. Studies by Sun and Perona (1998) and Mamassian and Goutcher (2001) examining light source perception propose an advantage for processing light from above and to the left, while others, like that by McManus et al. (2004), do not reliably find a leftward lighting bias. In aesthetics, Smith and Elias (2013) and Hutchison et al. (2011) have found leftward lighting to increase preferences, while Thomas et al. (2008) has found leftward lighting in advertising to be more common. However, several studies report preference reversals when participants' native language is read right-to-left. Results from studies exploring target-finding point to an upper visual field advantage, but are diverse, largely depending on the duration of presentation and stimuli used for targets and distractors (Previc & Blume, 1993; Rezec & Dobkins, 2004). Considering these varied results, our initial hypotheses of left-to-right readers' shortest average target identification durations for upper-left targets and right-to-left readers' shortest average target identification durations for upper-right targets may have been off, as reading direction appears to modulate lateral biases differently between tasks.

We investigated target finding in a novel way with right-to-left readers. Future target finding studies including groups of right-to-left readers should be carried out to elucidate conditions leading to advantages that may exist within this group. As target finding tasks using shape from shading stimuli typically are not concerned with shortest duration times based on target location, our analysis of this aspect is also novel and worthy of further examination with both left-to-right and right-to-left readers. If target finding does indeed follow Previc's (1998) model and occurs in the FcE, parvocellular visual cortical pathways of the ventral stream manage shape from shading information as well as target spatial location. This could lead to competition of resources within the ventral stream, and begin to explain our mixed results for target spatial location.

Key findings from the studies presented are the replication of previous findings of upper-left lighting facilitating shortest average duration times for target identification among left-to-right readers, and the novel finding of right lighting facilitating shortest average duration times for target identification among right-to-left readers. Consistent with findings from past research, both left-to-right and right-to-left readers displayed the shortest average duration times for targets located in the upper quadrants. Additionally, by using eye-tracking in the current set of studies we are able to say with confidence that individuals, regardless of native reading direction, pay the most attention to the upper quadrants in a shape from shading target finding task, with an interaction observed between native reading direction and durations examining a quadrant, when the two groups were run in the same study. The option of a common underlying mechanism remains a possibility when comparing findings from the current set of studies to outcomes of past research in the related fields of target finding, lighting biases, and pseudoneglect. Neurologically normal individuals have been found to exhibit biases in perception and attention, which are consistently leftward. In large part, findings supporting leftward biases in cognitive tasks such as lighting and image comparison have resulted from samples of Western participants, usually with a native language that reads left-to-right. Importantly, researchers have had less success replicating findings of leftward biases when using a representative sample of participants, including those with a non-left-to-right reading first language. It is likely that results from past studies finding leftward biases are, to some degree, not generalizable to all individuals.

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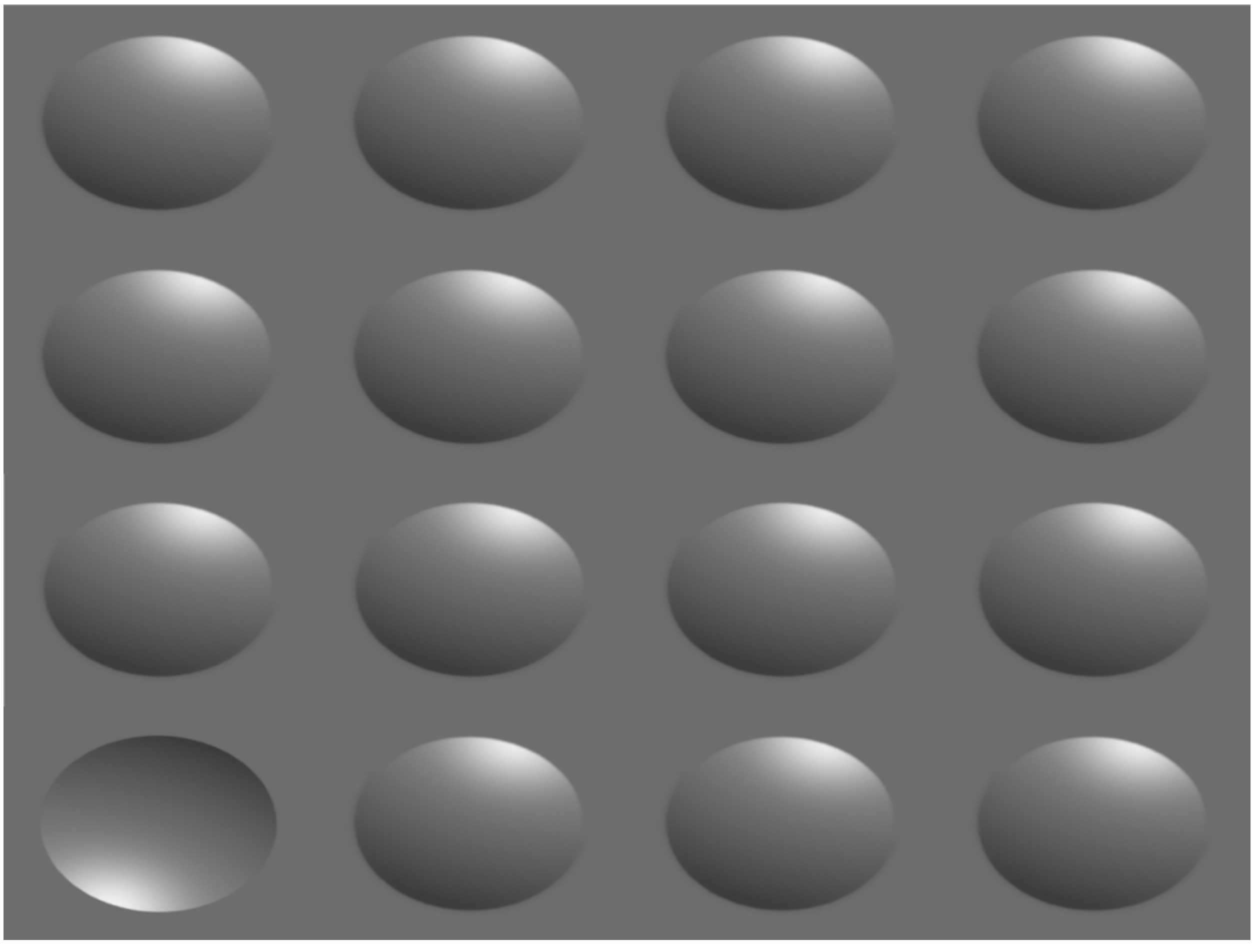
Appendix B
SAMPLE STIMULI USED IN STUDY 1, 2, & 3



Appendix C
WATERLOO HANDEDNESS AND FOOTEDNESS QUESTIONNAIRE-REVISED

PARTICIPANT QUESTIONNAIRE

Age: ________

Sex (circle one): **M** **F**

If you are a student, what is your major? _________________ Year of study? ____________

What was the **first** language you learned as a child? **English** **French** **Chinese** **Other: __________**

Do you have any hearing impairments? **Yes** **No**

Do you have any visual impairments (including colorblindness)? **Yes** **No**
If yes to either question, please specify:

What colour are your eyes? **Blue** **Brown** **Green** **Hazel** **Violet** **Other:_____**

What is your natural hair colour? **Blond** **Brown** **Black** **Red** **Auburn** **Other:_____**

Do you have any primary **biological** relatives (i.e., mother, father, brother, or sister) who are left-handed?
Yes **No** **Don't Know**
Do you have any **biological** extended family members (i.e., grandparents, ***biologically*** related aunts and uncles) who are left-handed? **Yes** **No** **Don't Know**

Please list any medications (including oral contraceptives) that you are currently taking:

Instructions: Please indicate your hand preference for the following activities by circling the appropriate response. If you **always** (i.e., 95% or more of the time) use one hand to perform the described activity, circle **Ra** or **La** (for **right always** or **left always**). If you **usually** (i.e., about 75% of the time) use one hand circle **Ru** or **Lu,** as appropriate. If you use both hands **equally often** (i.e., you use each hand about 50% of the time), circle **Eq.**

1. With which hand would you use a pair of tweezers?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
2. With which hand would you use a paintbrush to paint a wall?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
3. Which hand would you use to pick up a book?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
4. With which hand would you use to eat a bowl of soup?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
5. With which hand would you use the eraser on the end of a pencil?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
6. Which hand would you use to pick up a piece of paper?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
7. Which hand would you use to draw a picture?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
8. Which hand would you use to hammer a nail?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
9. Which hand would you use to insert a plug into an electrical outlet?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
10. Which hand would you use to throw a ball?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
11. In which hand would you hold a needle while sewing?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
12. In which hand would you use to turn on a light switch?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

13. Which hand do you use for writing? **La** **Lu** **Eq** **Ru** **Ra**

14. Which hand would you use to saw a piece of wood with a hand saw? **La** **Lu** **Eq** **Ru** **Ra**

15. Which hand would you use to open a drawer? **La** **Lu** **Eq** **Ru** **Ra**

16. Is there any reason (e.g., injury) why you have changed your hand preference for any of the above activities?
YES **NO**

17. Have you been given special training or encouragement to use a particular hand for certain activities?
YES **NO**

18. If you have answered YES to either Questions 16 or 17, please explain.

Instructions: Please indicate your foot preference for the following activities by circling the appropriate response. If you **always** (i.e., 95% or more of the time) use one foot to perform the described activity, circle **Ra** or **La** (for **right always** or **left always**). If you **usually** (i.e., about 75% of the time) use one foot circle **Ru** or **Lu** (for **right usually** or **left usually**). If you use both feet **equally often** (i.e., you use each hand about 50% of the time), circle **Eq**. Please do not simply circle for all questions, but imagine yourself performing each activity in turn, and then mark the appropriate answer.

19. Which foot would you use to kick a stationary ball at a target straight ahead? **La** **Lu** **Eq** **Ru** **Ra**

20. If you had to stand on one foot, which foot would it be? **La** **Lu** **Eq** **Ru** **Ra**

21. Which foot would you use to smooth sand on a beach? **La** **Lu** **Eq** **Ru** **Ra**

22. If you had to step up onto a chair, which foot would you place on the chair first? **La** **Lu** **Eq** **Ru** **Ra**

23. Which foot would you use to stomp on a fast moving bug? **La** **Lu** **Eq** **Ru** **Ra**

24. If you were to balance on one foot on a railway track, which foot would you use? **La** **Lu** **Eq** **Ru** **Ra**

25. If you wanted to pick up a marble with your toes, which foot would you use? **La** **Lu** **Eq** **Ru** **Ra**

26. If you had to hop on one foot, which foot would you use? **La** **Lu** **Eq** **Ru** **Ra**

27. Which foot would you use to help push a shovel into the ground? **La** **Lu** **Eq** **Ru** **Ra**

28. During relaxed standing, most people have one leg fully extended for support and the other slightly bent. Which leg do you have fully extended first? **La** **Lu** **Eq** **Ru** **Ra**

29. Is there any reason (i.e. injury) why you have changed your foot preference for any of the above activities?
YES **NO**

30. Have you ever been given special training or encouragement to use a particular foot for certain activities?
YES **NO**

31. If you have answered YES for either question 29n or 30, please explain:

Appendix D

CONSENT FORM FOR SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: LEFT-TO-RIGHT READERS

You are invited to participate in a research project entitled Biases in Perception of Light Source. Please read this form carefully, and feel free to ask questions you might have.

Researcher: Izabela Szelest, Department of Psychology at the University of Saskatchewan, Phone: (306) 966-6699.
Supervisor: Dr. Lorin Elias, Department of Psychology at the University of Saskatchewan, Phone: (306) 966-6670.
Purpose and Procedure: This research investigates the role of light source on perceptual bias. You may be asked to compare two images and determine which one is convex (or concave). To make a response you will press the corresponding key on the computer keyboard. You may also be asked to view a set of sixteen spheres and fixate on the odd one out while having your gaze tracked using the eye tracker. As compensation, you will be granted one credit for every 30 minutes of your participation.

Potential Benefits: This study is designed to have scientific benefit in further understanding perception of objects biased by light source. As a direct benefit to you, the participant, you may gain a greater understanding on how experimental research is conducted.

Potential Risks: There are no known risks associated with participation in this study.

Storage of Data: The data obtained in this study will be stored separate from the consent forms with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years after the study is completed. If the data is no longer needed and required to be destroyed, it will be destroyed beyond recovery.

Confidentiality: Although the data from these research projects may be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify any individuals.

Right to Withdraw: Your participation in this study is voluntary, and you can answer only those questions that you are comfortable with. There is no guarantee that you will personally benefit from your involvement. The information that is shared will be held in strict confidence and discussed only with the research team. You may withdraw from the research project for any reason, at any time, without penalty of any sort and it will not affect your course credit. If you withdraw from the research project at any time, any responses you made will not be liked to your name and therefore withdrawal of data is only possible up until the completion of the experiment. Your right to withdraw data from the study will apply until data has been pooled. After this it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.
Questions: If you have any questions concerning the research project, please feel free to ask at any point; you are also free to contact the researchers at the numbers provided if you have other questions. This research project has been approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board on November 22, 2010. Any questions

regarding your rights as a participant may be addressed to that committee through the Ethics Office (966-2084). Out of town participants may call collect. Results may be obtained by contacting Dr. Lorin Elias.

Consent to Participate:

I have read and understood the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project, understanding that I may withdraw my consent at any time. A copy of this Consent Form has been given to me for my records.

______________________________	______________________________
(Name of Participant)	(Date)
______________________________	______________________________
(Signature of Participant)	(Signature of Researcher)

Appendix E
DEBRIEFING FORM FOR SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: LEFT-TO-RIGHT READERS

Thank you so much for being a part of our study. With your help we are able to investigate how lighting angle affects how we perceive objects. Normally when an object (in this case a sphere) is lit from the top left side, it is perceived as convex (bulging out). However, when we take the same sphere and light it from bottom right, we will perceive it as concave (bulging in). Interestingly, sometimes this phenomenon is easier to observe than others. It is possible that some of these inconsistencies are a result of an attentional left-sided bias, also known as pseudoneglect. Neurologically healthy people are more likely to judge size, colour, or numerosity as more desirable (based on the goal of the experiment) if it is located on the left side of the visual filed.

Researchers attempt to further understand and explain these perceptual biases. One of the explanations states that the right brain hemisphere is relatively more dominant in processing spatial information and thus favors the left side of space. Thus, common effects such as reporting a darker image on the left side from two identical images are widely observed. Although the relationship between these biases and perception of light sources is still to be determined, we know that its impact reaches many areas, such as artistic paintings and daily driving.

In this experiment, you were presented with a set of sixteen spheres; fifteen were lit from the same angle and one was lit from the opposite angle. Your goal was to find the sphere which was unlike the other ones. An eye tracker was used to determine the pattern of eye movements and scanning strategies when searching for this odd sphere. The research conducted so far in this area shows that we are faster and more accurate at locating the odd sphere when it is lit from the left side**.** This can be a result of how objects are perceived everyday as a result of the position of the sun. There is also a neurological explanation as to why we perceive objects such way. As mentioned above, a spatial bias may play a role here. If pseudoneglect plays a role in how we perceive these images, then a stronger bias should be on the left side. If however, pseudoneglect does not influence how we judge convexity in this case, the results should show the same effect for images displayed on the left and right side of the screen.

If you are wondering why we were not able to provide this information before you began the experiment, the answer is that we didn't want to alter your response in the experiment. If we had told you that we are expecting that you should see the items which were black on the left as darker, then we would not be able to conclude that this effect is valid. This is known as *demand awareness effect*. When working with humans, this effect may potentially cause serious problems with the obtained results. If you were to alter your response based on provided information, then you may not be using the same psychological process which we are interested in studying. Such research would create conflicting results and delay scientific advancement. Thus, we would also appreciate if you do not tell your friends about the rationale/ methodology of the study as they may also participate.

Once again, thank you so much for being a part of your study. It is participants like you that allow us as researchers to investigate interesting, but complex, workings of our brain. It is our hope that your participation will not only help to advance our research, but that it would also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Izabela Szelest at 306-966-6699 or Dr. Lorin Elias at 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

Appendix G
CONSENT FORM FOR SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: LEFT-TO-RIGHT & RIGHT-TO-LEFT READERS

You are invited to participate in a research study entitled *Lighting Direction and Visual Search Tasks*. Please read this form carefully, and feel free to ask any questions you might have about the study.

Researcher: *Austen Smith*, Department of Psychology, *966 6699, austen.smith@usask.ca*.

Supervisor: L*orin Elias*, Department of Psychology, *966 6670, lorin.elias@usask.ca*.

Purpose and Procedure: This research investigates the role a light source may have during a target finding task. You will be asked to view images and identify a specified target within the image. To indicate that you have found it, you will press the corresponding key on the keyboard. This study will take approximately 30 minutes to complete. As compensation, you will be granted one credit (participant pool sign up) or ten dollars (poster advertisement sign up).

Potential Benefits: This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding the relationship between visual perception and reading direction. Your participation in this study may also provide you with a greater understanding of how the research process works.

Potential Risks: There are no known risks associated with participation in this study

Storage of Data and Confidentiality: The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to withdraw: Your participation in this study in this study is voluntary. You may withdraw from the study for any reason, at any time, without penalty, loss of research credit for the session, or loss of monetary compensation (if applicable). The information that you share will be held in strict confidence and discussed only with the research team. There is no guarantee that you will personally benefit. If you withdraw from the study, any data that you have contributed will be destroyed beyond recovery.

Questions: If you have any questions concerning the study, please feel free to ask at any point; you are also free to contact the researchers at the numbers provided if you have other questions. This research study has been approved on ethical grounds by the University of Saskatchewan Behavioural Research Ethics Board on February 9, 2012. Any questions regarding your rights as a participant may be addressed to that committee through the Ethics Office (966-2084). Out of town participants may call collect. Results of the study may be obtained by contacting Dr. Lorin Elias.

Consent to Participate:

I have read and understand the description of the research study provided above. I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study described above, understanding that I may withdraw my consent to participate at any time. A copy of this consent form has been given to me for my records.

______________________________	______________________________
(Name of Participant)	(Date)
______________________________	______________________________
(Signature of Participant)	(Signature of Researcher)

Appendix H
DEBRIEF FORM FOR SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: LEFT-TO-RIGHT & RIGHT-TO-LEFT READERS

The human visual system is lateralized in such a way that information entering through the left visual field is primarily processed in the right hemisphere of the brain, and right visual field information is handled mostly by the left hemisphere of the brain. These ‘cross-overs’ between side of brain and side of body are quite common and are found in many instances, including hearing and handedness. When a function or perception is processed by the opposite half of the brain (right hand – left hemisphere, for example) it is said to be *contralateral*. Each of the hemispheres of the brain has different responsibilities (as well as some shared ones), which often leads to asymmetries in human function and perception.

In this study, we are looking at perceptual asymmetries in the human visual system. As you examined the images comprised of multiple 2-dimensional circles, you would have noticed that the different shading of circles makes some of them appear 3-dimensional – either bulging out of or sinking into the screen. This effect is strongest when the circles are shaded in a way so that they appear to be lit from above or below (as opposed to shaded to appear like light is coming from the side). This is consistent with how our visual system typically examines objects (a horizontal shading gradient) and is thought to be a result of living in a solar system with one, consistent, overhead light source – the sun.

Intuitively, one might think that a light source from directly overhead is preferred when examining images with varying angles of illumination (such as the shaded circles). This assumption is, in fact, mistaken. Research has found that a leftward light source is actually preferred. This phenomenon has been termed the *leftward lighting bias* and has been replicated through various tasks using ambiguously lit images (such as the circles in this experiment) as well as in more complex images, like magazine advertisements. In this experiment, the *leftward lighting bias* may play a role in the time it takes for you to find the target in each image. Despite many different ideas about the occurrence of this phenomenon, the research community has yet to reach any conclusions. One factor that has yet to be fully examined is the native reading direction of those supplying the data… YOU – the participant! Most of the research examining the *leftward lighting bias* has been conducted with left to right readers.

Our scanning patterns of images mirror those of reading text – a ‘Z’ pattern, starting in the upper left moving across to the upper right, cutting down to the bottom left, and then over to the bottom right. Presumably then, those who read in a right to left direction scan images in a mirrored ‘Z’. The intense practice and training that accompanies reading may be central to understanding the *leftward lighting bias*. The importance of scanning patterns is the reason we tracked your eye movements throughout the experiment.

This information was not available to you before the experiment because we didn’t want to alter your responses. When working with humans, this effect may potentially cause serious problems with the obtained results. If you were to alter your response based on provided information, then you may not be using the same psychological process that we are interested in studying. Such research would create conflicting results and delay scientific advancement. Thus, we would also appreciate if you do not tell your friends about the rationale/ methodology of the study as they may also participate.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith at austen.smith@usask.ca, 306-966-6699 or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

Appendix J

CONSENT FORM FOR SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: RIGHT-TO-LEFT READERS

You are invited to participate in a research study entitled ***Native Right to Left Readers Visual Inspections of Images***. Please read this form carefully, and feel free to ask any questions you might have about the study.

Researcher: *Austen Smith*, Department of Psychology, *966 6699, austen.smith@usask.ca*.

Supervisor: *Lorin Elias*, Department of Psychology, *966 6670, lorin.elias@usask.ca*.

Purpose and Procedure: This research investigates the way in which individuals whose native language is read from right to left visually explore images. You will be asked to look at images on a computer screen while your eye movements are recorded with a non-invasive eye tracking camera, which can be turned off at your request at any time. You will be asked to answer yes or no questions about some images. You may choose not to discuss any topic you wish. This study will take approximately 30 minutes to complete and as compensation you will be granted ten dollars.

Potential Benefits: This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding the relationship between visual perception and reading direction. Your participation in this study may also provide you with a greater understanding of how the research process works.

Potential Risks: There are no known risks associated with participation in this study

Storage of Data and Confidentiality: The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to withdraw: Your participation in this study in this study is voluntary. You may withdraw from the study for any reason, at any time, without penalty, loss of research credit for the session, or loss of monetary compensation (if applicable). The information that you share will be held in strict confidence and discussed only with the research team. There is no guarantee that you will personally benefit. If you withdraw from the study, any data that you have contributed will be destroyed beyond recovery.

Questions: If you have any questions concerning the study, please feel free to ask at any point; you are also free to contact the researchers at the numbers provided if you have other questions. This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (866) 966-2975. Results of the study may be obtained by contacting Dr. Lorin Elias.

Consent to Participate: I have read and understand the description of the research study provided above. I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study described above, understanding that I may withdraw my consent to participate at any time. A copy of this consent form has been given to me for my records.

________________________________	________________________
(Name of Participant)	(Date)
________________________________	________________________________
(Signature of Participant)	(Signature of Researcher)

Appendix K

DEBRIEFING FORM FOR SHAPE FROM SHADING STIMULI IN A TARGET FINDING TASK: RIGHT-TO-LEFT READERS

The human visual system is lateralized in such a way that information entering through the left visual field is primarily processed in the right hemisphere of the brain, and right visual field information is handled mostly by the left hemisphere of the brain. These ‘cross-overs’ between side of brain and side of body are quite common and are found in many instances, including hearing and handedness. When a function or perception is processed by the opposite half of the brain (right hand – left hemisphere, for example) it is said to be *contralateral*. Each of the hemispheres of the brain has different responsibilities (as well as some shared ones), which often leads to asymmetries in human function and perception.

It is believed that we look at images in a similar manner to reading text. For those whose native language is read in a left to right direction, scanning patterns of images roughly follow a ‘Z’ shape, starting in the upper left moving across to the upper right, cutting down to the bottom left, and then over to the bottom right. One of the aims of the study you just participated in is to determine if individuals whose native language is read from right to left explore images the same way. A right to left reader’s scan patterns may mirror those of a left to right reader, or they may follow an ‘S’ shape, similar to the direction text is read (starting in the top right corner, moving across to the left, and then down to the bottom right, and over left again).

Understanding any differences that exist between left to right readers and right to left readers may help our endeavors to make sense of the *Leftward Lighting Bias*. Intuitively, one might think that an overhead light source originating from directly above is preferred when examining images, perhaps because of living in a solar system with one, consistent, overhead light source – the sun. This assumption is, in fact, mistaken. Research has found that a leftward light source is actually preferred and this has been termed the *leftward lighting bias*. Various laboratory tasks using ambiguously lit images, such as shaded circles and texture patches, as well as more complex images like magazine advertisements have replicated the *leftward lighting bias*.

Most of the research finding a *leftward lighting bias* has been carried out with people whose native language reads left to right. In trying to understand the reasons for the *leftward lighting bias*, it is important for us to find out if it occurs only in certain populations or across all individuals. If the *leftward lighting bias* disappears or is not as pronounced in individuals who read right to left, conclusions about how the brain handles visual information will have to be adjusted accordingly.

We would appreciate it if you do not tell your friends about the rationale/ methodology of the study as they may also participate. Although knowing this information and/ or our hypothesis will not likely alter visual scans or answers a participant may make, the most accurate results are obtained when a participant carries out the task without thinking about where they are looking.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith at austen.smith@usask.ca, 306-966-6699 or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.